

Quartz Micro-textures as Proxies for Deciphering Sedimentary Depositional Environments – A Case Study from Red Hills, Tamil Nadu, India



Earth Science

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ABSTRACT

Micro-textures recorded on the surfaces of quartz grains provide evidence of past environment, as these grains are predominantly used due to their superior resiliency to degradation by natural physical and chemical processes. They can withstand a variety of processes leading up to their deposition without being completely obliterated. Environmental processes, such as transport by rivers, create unique micro-texture surfaces that can be observed under high magnification with a scanning electron microscope (SEM). A ferruginous sandstone outcrop near a small village called Manjanakaranai, near Red Hills in Tamil Nadu State, India, was selected for comprehending its sedimentary depositional environment using micro-textures on quartz grain surfaces. Analysis and interpretation of SEM photographs of selected quartz grains from different levels in the outcrop reveal that the sediments were transported by running water and deposited in a fluvial (riverine) sedimentary environment.

INTRODUCTION

Micro-textures recorded on the surfaces of quartz grains provide evidence of past environment. Environmental processes, such as transport by rivers, create unique micro-texture surfaces that can be observed under high magnification with a scanning electron microscope (SEM). These micro-textures and their proportions are diagnostic of the mode of transportation, allowing investigators to infer the mode of transportation and subsequent process of deposition (Al-Saleh and Khalaf, 1982). The SEM has been shown to be a particularly effective tool in grain surface studies. Scanning electron microscopy (SEM) analysis of quartz grain surface features has been used since the 1960's to ascertain grain transport history after liberation from provenance rock and prior to final deposition (e.g. Krinsley and Takahashi, 1962; Krinsley and Donahue, 1968; Krinsley and Doornkamp, 1973; Mahaney, 2002).

Although SEM analysis of quartz grain surfaces is not a Rosetta stone to infer all styles of transport, a few environments can be defined by the surface micro-texture character. For example, wet-based glaciers with high basal and internal shear impart a suite of micro-textures reflecting grain-to-grain stylus contact through sustained high shear stress, whereas percussion transport produces grain-to-grain impact features on grain surfaces from saltation (Mahaney and Kalm, 2000; Mahaney, 2002; Whalley and Langway, 1980). The different impact features and the abrasion marks on the quartz grains are formed during transportation in different dynamic environments and they generally record those mechanical processes. The features of chemical origin consist of various types of etching and overgrowth (Madhavaraju *et al.*, 2009).

Quartz grains from marine environment generally exhibit V-shaped patterns (V's), straight and curved scratches, with several protrusions (Krinsley and Doornkamp, 1973; Higgs, 1979; Madhavaraju and Ramasamy, 1999; Madhavaraju *et al.*, 2004, 2006). The presence of sub-rounded features, bulbous edges along with certain amount of V-shaped pits indicate fluvial origin (Linde, 1987; Mahaney, 1998). Quartz grains from glacial origin display parallel striations, chatter marks and imbricated grinding features (Margolis, 1968; Higgs, 1979; Mahaney, 1995a, b; Mahaney *et al.*, 1996). On the basis of the different types of micro-textures observed on the quartz grains, it is possible to distinguish the particular depositional

environments such as marine, fluvial, aeolian and glacial. The purpose of the present study is to investigate the micro-textures present on quartz grains from a Tertiary ferruginous outcrop near Red Hills, Tamil Nadu, India to infer the sedimentary depositional environment.



Fig. 1 Google Earth map showing the ferruginous outcrop (FoC) at Manjanakaranai

METHODOLOGY

Thirteen samples were collected at intervals of roughly 1 m, from the top of the outcrop to the base (Fig. 1). Samples were collected based on variations in composition and clast sizes. Representative samples are collected on the basis of colour, mineral content and particle size. The collected samples were highly friable, so light hammering was sufficient to break them down into smaller fragments. The sample preparation method was after Krinsley and Doornkamp (1973) and Helland and Holmes (1997). Sediments were then sieved using test sieve ASTM 20 (opening = 850 μm), followed by ASTM 40 (420 μm). The sieved sediment samples were then washed over a test sieve ASTM 60 (250 μm). These sieves were used to isolate quartz grains with a size range between 200 and 400 μm . The washed and sieved samples were then soaked in water and left to stay overnight to facilitate deflocculation, after which the water was decanted. They were then subjected to 30% HCL treatment for over an hour to remove the carbonate coatings, if present. Once HCL treatment was done, the sediments were washed repeatedly with distilled water and oven-dried at 50° C. A fraction of the dried sediments was taken in a picking tray and 25 quartz grains were randomly picked from each of the thirteen samples and stored in small glass vials. These are considered as sufficient to understand the variations present in a single sample and also to interpret the depositional history (Krinsley and Doornkamp, 1973; Baker, 1976). Following this, the grains were then treated with stannous chloride (SnCl₂) solution to remove iron coatings and washed thoroughly with distilled water.

The thus prepared quartz grains were mounted on stubs, sputter-coated with gold, and examined using a JEOL JSM 6360 scanning electron microscope (SEM). Quartz grain micro-textures were analyzed under the SEM using the checklist approach, as used previously by various authors (Bull, 1978; Higgs, 1979; Williams and Morgan, 1993). The various types of quartz grain micro-textures have been established by Higgs (1979) on the basis of published data (Krinsley and Donahue, 1968; Krinsley and Margolis, 1971; Margolis and Kennet, 1971; Krinsley and Doornkamp, 1973; Le Ribault, 1975).

RESULTS AND DISCUSSION

Mahaney (2005) enlisted 41 different micro-textures exhibited by quartz surface encrypting the records of events overprinted with time. Often it is possible to reconstruct the entire environment history of a grain as well as related time involved by studying closely the pre-weathering and weathering features. Sand grains usually travel as traction or saltation load (Bagnold, 1941) and may be subjected to a succession of high energy collisions. During collisions, the kinetic energy of each particle is converted, at least partially, into elastic energy in the grain. The energy wave or vibration may bounce back and forth within a given grain a number of times, although it is not known how this affects the grain surface. The result of these collisions, termed "abrasion fatigue" by Pascoe (1961), is a disrupted lattice type of structure on grain surface. This makes the surface of the grains physically and chemically reactive and may cause small silt and clay particles to attach to the grains until they are removed by additional abrasion. The shape of grains in the deposit regardless of their size depends on a number of factors, including: (i) initial shape of the grain; (ii) physical and chemical features; (iii) duration of the process; (iv) character and environment of transport; and (v) type and intensity of the weathering following sedimentation.

Visual analysis of the SEM photographs of surfaces of different quartz grains from various levels in the outcrop exhibited diagnostic fluvial imprints. The most diagnostic micro-texture of the fluvial process is the V-shaped percussion ridge/scar. Well preserved in quartz, percussion ridges are also found on other grains, including heavy minerals. The higher the flow regime, the greater the frequency with which this micro-texture appears on a random sample of grains. This micro-texture may also be present on glacial grains, especially grains emplaced by warm-based glaciers, where water is available within and at the base of the ice, and when material moves at high velocity (Mahaney and Kalm, 1996). The presence of these micro-textures is taken as evidence of near-catastrophic flow; however, much more work needs to be done with respect to correlating micro-textures with increasing stream velocity (Mahaney, 2002). Abrasion, seen primarily as a rounding factor with quartz, is also important in wearing fracture down to plane surface and, in some cases, obliterating them. The available evidence indicates that upper flow regimes produce greater degrees of abrasion and rounding than middle or lower flow regimes, and tend to obscure any previous micro-texture signature, especially over long distance transportation.

In the present study, eight distinct micro-textures were identified, the combination of which are diagnostic of a fluvial environment: (i) extensive etchings on the surface; (ii) edge roundings; (iii) pits; (iv) linear steps; (v) inverted V-shaped ridges; (vi) parallel linear ridges with parallel linear grooves; (vii) intense abrasion features; and (viii) grain elongation, five of which are illustrated (Plate 1; figs. 1a-d).

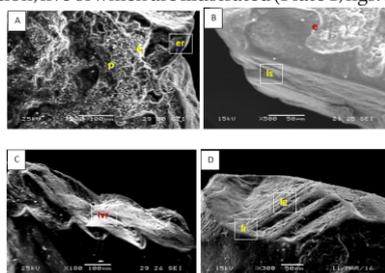


Plate 1 (SEM photographs of quartz grain surfaces showing: (A-230x) etchings (e), edge roundings (er), and pits (p); (B-500x) etchings (e) and linear steps (ls); (C-180x) inverted V-shaped ridges (ivr); and (D-300x) parallel linear ridges (lr) with parallel linear grooves (lg).

The results indicate that a common micro-textural fingerprint exists among the various grains collected from the study area. Inverted V-shaped patterns (ridges), linear steps, parallel linear ridges with linear parallel grooves and associated micro-textures are characteristic of moderate- to high-energy sub-aqueous conditions as suggested by Margolis and Krinsley (1974), and mainly occur on quartz grains from shallow marine, fluvial (high energy) and deltaic (seaward) environments (Higgs, 1979). V-shaped patterns result from both mechanical and chemical processes. Those that result from mechanical processes exhibit irregular shape and randomly oriented patterns, whereas V-shaped patterns having regular outer edges with oriented patterns result from chemical etching. V-shaped features of mechanical origin are caused by grain-to-grain collision in a sub-aqueous environment when one grain strikes another under high-energy conditions (Manker and Ponder, 1978).

CONCLUSION

Based on the micro-textures exhibited by quartz grains from the ferruginous outcrop at Manjankaranai, it can be concluded that they were dominantly transported to the region by fluvial processes and subsequently deposited. In composition and other geological aspects, the outcrop present in this area is quite similar to the Cuddalore Sandstone formation and the Thiruvakkarai ferruginous grit. A comparative study of micro-textures among the quartz grains from these three areas would establish if these three outcrops are geologically penecontemporaneous.

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