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Roundness and surface features of quartz grains in Middle Devonian deposits of the East Baltic and their palaeogeographical implications

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Abstract. The roundness and surface texture of quartz grains were studied in Devonian sediments of 32 drill cores. Roundness was estimated in more than 800 samples and surface textures were examined under scanning electron microscope on 70 grains. The grains were mostly subrounded to subangular. The concentration of rounded grains in some beds of the Pärnu Formation (Fm.), the basal beds of the Leivu Fm., and the upper part of the investigated sequence indicates zones of sediment recycling and reworking. Based on the distribution of roundness degrees of quartz grains, some possible ancient coastlines in Pärnu time were defined.

Variations in quartz surface textures were detected at different stratigraphical levels, whereas 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 (Burtnieki and Gauja formations and on some levels of the Pärnu Fm.) preliminary relief of grains was smoothed and obliterated. The diagenetic dissolution features were more frequent in the Pärnu Fm., Kernave Fm., and lower part of the Aruküla Fm., where intercalation of dolomitic and siliciclastic rocks is common. Possible chemical etching in Devonian soil profiles was observed in the upper part of the section. Data on the roundness of particles and surface textures of quartz grains, and their horizontal and vertical variability help to clarify the history of basin evolution and to distinguish stratigraphical discontinuites.

Key words: East Baltic, Devonian, roundness of detrital particles, surface texture of quartz, SEM.

INTRODUCTION

The shape of sedimentary particles is an important physical feature that may provide information about the sedimentary history of a deposit and the behaviour of particles in a transporting medium. Pettijohn (1975) concluded that the roundness of a particle is the sum of its abrasional history. Quartz is the standard mineral for grain-shape analysis (Beal & Shepard 1956; Shepard & Young 1961; Griffiths 1967). The shape of detrital quartz grains changes due to mechanical and chemical processes during erosion, transportation, and deposition. Roundness reflects the degree of abrasion of clastic particles and provides evidence about the medium, time, and distance of transport. Rounding of grains by dissolution processes during weathering is described in Crook (1968). Grain-shape variations have mainly been studied in modern depositional environments (Mazzullo et al. 1986), but the data obtained contribute to resolving also sedimentological problems related to ancient rocks (Datta 2005; Madhavaraju et al. 2006). Many studies have used scanning electron microscope (SEM) analysis to interpret the mechanical and chemical processes that characterize the shape and surface features of quartz grains and their connection with different depositional environments (Mazzullo et al. 1986; Mazzullo & Magenheimer 1987; Pye & Mazzullo 1994; Okhravi & Amini 2001; Cherian et al. 2004; Kasper-Zubillaga et al. 2005). Grain surface analysis allows distinction of wind-transported quartz particles (Mazzullo et al. 1986), but also differentiation between dune and beach (Mazzullo et al. 1986; Kasper-Zubillaga, 2005) and glacial sediments (Mahaney & Kalm 2000; Pandey et al. 2002). Roundness and surface textures are valuable characteristics also for the study of fluvial environments (Oakey at al. 2005; Shine 2006). The surface textures of quartz grains have been used to determine the depositional agents and distinguish different steps in their sedimentary evolution (Cardona et al. 1997).

In the present paper the roundness and surface textures of quartz grains of Devonian sedimentary rocks are examined in drill cores of the East Baltic basin (Fig. 1). Up to now, the surface textures of quartz grains have been studied besides Quaternary deposits only in some samples of the Devonian Aruküla Formation (Fm.; Mahaney & Kalm 2000; Mahaney 2002) and in Cambrian deposits of Estonia (Kurvits et al. 2000).

Fig. 1. Location of the studied drill cores.

GEOLOGICAL BACKGROUND

The Devonian sequence of the East Baltic is mainly represented by terrigenous rocks with carbonate complexes and interlayers. The sequence considered in the present work ranges from the Lochkovian Tilze Regional Stage (RS) to the Givetian Gauja RS with a total thickness of more than 500 m (Fig. 2). The study is focused mainly on the section from Rezekne to Gauja formations (Fms). The lowermost part of the section, the Rezekne and Pärnu Fms, is mostly represented by weakly clay-cemented siliciclastic rocks, containing rare interlayers of dolostone and dolomitic marlstone. The siliciclastic complex is overlain by carbonate deposits of the Vadja and Leivu Fms, represented by a complex of intercalating dolomitic marlstones and dolostones with claystone and siliciclastic interlayers (Kleesment & Shogenova 2005). The thickness of the carbonate complex, especially of Leivu deposits, increases markedly from north to south, from about 20 m in northeastern Estonia to 130 m in southern Latvia and Lithuania (Figs 3 and 4). In the lowermost part of the Vadja Fm. a layer of sedimentary breccia is distributed throughout the shallow Baltic basin (Tänavsuu-Milkeviciene et al. 2008). The dolostone of the Vadja Fm. is often cracked and includes vugs and stretches filled with crystalline dolomite or calcite. Desiccation cracks have been found on bedding planes (Kleesment & Shogenova 2005). The lowermost part of the Leivu Fm. contains also clastic material. In western Latvia and Lithuania gypsum-cemented sandstones up to 9 m thick occur in this level (Remte, Liepaja, and Palanga cores; Fig. 4). The overlying Kernave Fm. is 20–50 m thick and is represented by a horizontal or lenticular medium- to thin-bedded sequence of fine to very fine-grained sandstone including interlayers of siltstones, claystones, and dolomitic marlstones (Kleesment & Shogenova 2005). The upper part of the studied section (Aruküla, Burtnieki, and Gauja Fms), with a total thickness of about 100 m, is mainly represented by weakly cemented siliciclastic rocks (Figs 2–5). Quartz is the dominant mineral in the examined rocks, accompanied by lesser amounts of feldspars and mica (Kleesment & Mark-Kurik 1997).

Series	Stage	Regional stage	Formation	Member, Beds	Main lithology
MIDDLE DEVONIAN	Givetian	Amata	Amata		Sandstone
		Gauja	Gauja	Lode	
				Sietini	
		Burtnieki	Burtnieki	Abava	Sandstone
				Koorküla	
				Härma	
		Aruküla	Aruküla	Tarvastu	
				Kureküla	
				Viljandi	Sand- and siltstone
	Eifelian	Narva	Kernave		
			Leivu		Dolomitic marl- and dolostone
			Vadja		
		Pärnu	Pärnu		Sandstone
LOWER DEVONIAN	Emsian	Rezekne	Rezekne		
	Pragian	Kemeri	Kemeri		
	Lochkovian	Tilze	Tilze		

Fig. 2. Stratigraphy and main lithology of the examined sequence.

MATERIAL AND METHODS

Together with data on mineralogy, grain size distribution, and sorting, quantitative data on the roundness of quartz grains were obtained. In some sections additionally roundness values were counted in thin sections. The sample set for the present study consists of more than 800 samples and 120 thin sections taken from 32 drill cores (Fig. 1). Besides mineralogical analysis, the roundness of quartz grains of the very fine sand fraction (0.063–0.1 mm) was determined. The degree of roundness was estimated visually. From each sample 100 grains were analysed. In the years 1975–85 the classification with 19 roundness classes, suggested by Jershova (1962), was used. Later five roundness classes were distinguished following Krumbein & Sloss (1963). All collected data were re-estimated for four roundness classes proposed by Blott & Pye (2008; Figs 2–5).

The shapes and surface textures of 70 quartz sand grains were examined with a Zeiss EVO MAIS scanning electron microscope (SEM) at 10 kv. Grains with the

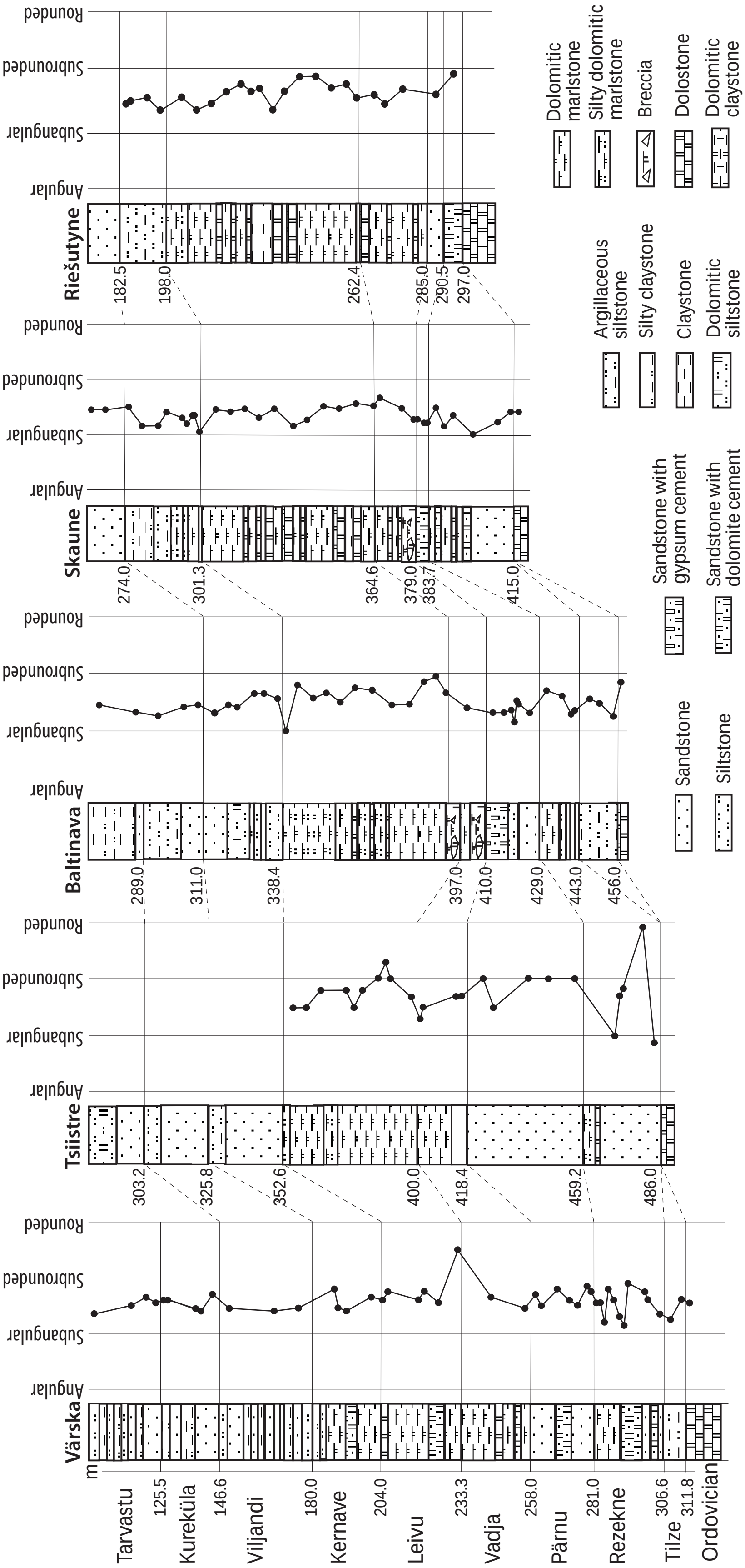


Fig. 3. Cross-correlation and roundness of quartz grains in profiles of selected cores in the eastern part of the studied area. Formation names on the left side.

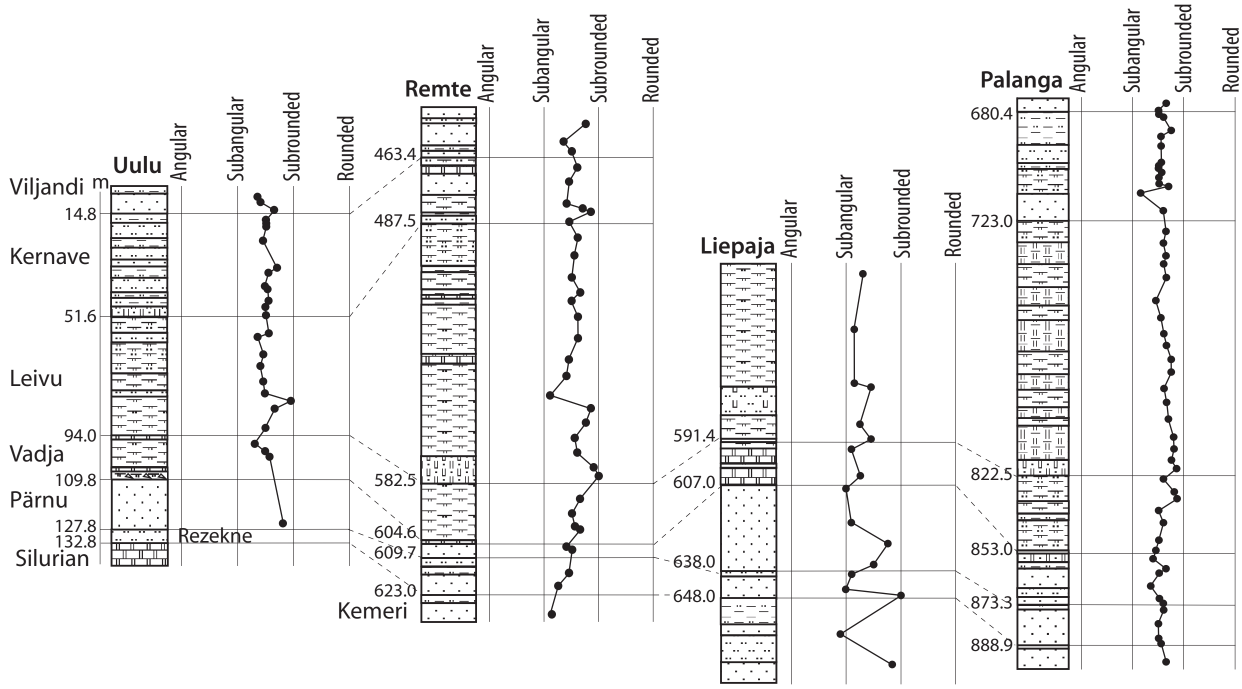


Fig. 4. Cross-correlation and grain roundness profiles of sections in the western part of the studied area. For legend see Fig. 3.

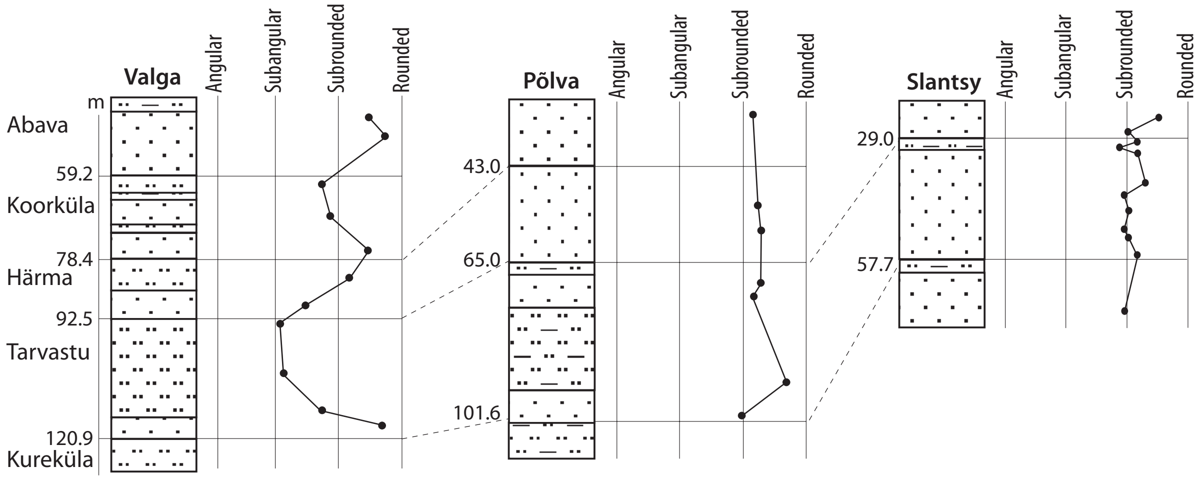


Fig. 5. Grain roundness profile for the upper part of the studied sequence. For legend see Fig. 3.

size of 0.1–0.3 mm were picked by hand under light microscope from 31 samples of 11 drill cores (Slantsy, Kavastu, Põlva, Baltinava, Skaune, Drissa, Riešutyne, Tõrva, Uulu, Kihnu, and Remte) and some outcrops of southeastern Estonia, representing the stratigraphic interval from Rezekne to Gauja Fms. All grains were photographed in full view, most of them also at higher magnifications.

RESULTS

Roundness

Spherical and moderately spherical subangular to subrounded quartz grains prevail in the studied sections (Figs 3–6). The high abundance of such grain type is attributed largely to the original outline of the grain in source rock and partly to the moderate distance of

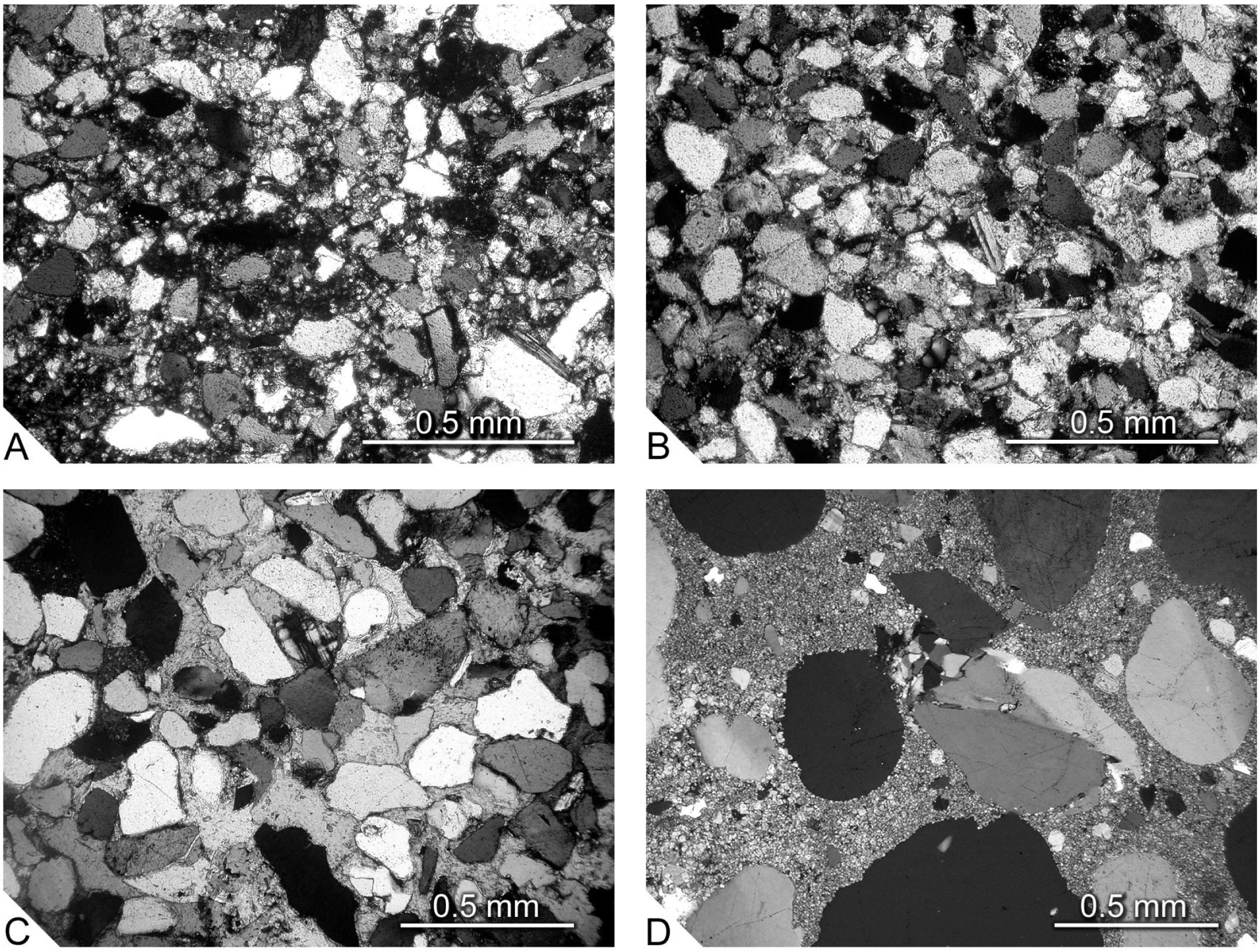


Fig. 6. Examples of usual grain roundness in thin sections. **A**, Kureküla Beds, Tsiistre core, 300.6 m, GIT 550-15. **B**, Vadja Fm., Tsiistre core, 415.6 m, GIT 550-36. **C**, Rezekne Fm., Värska core, 293 m, GIT 550-209. **D**, basal part of the Leivu Fm., Värska core, 257.5 m, GIT 441-56. The samples are housed at the Institute of Geology at TUT (GIT).

transportation (Plink-Björklund & Björklund 1999). Variation in roundness was recorded in different levels, whereas some clear trends were revealed (Figs 3–5). In rocks of the Rezekne and Pärnu Fms roundness varies considerably: levels with the prevalence of subrounded grains alternate with those dominated by subangular grains, containing a higher proportion of angular grains. This tendency is especially well expressed in the Pärnu Fm. in the Kihnu, Uulu, Tõlla, Võru, Mehikoorma, and Värska sections in the northern part, and in the Liepaja, Liepkalns, Katlakalns, and Atašiene sections in the southern part of the study area. In these sections beds with rounded grains forming 30–35% alternate with beds with the respective value of 10–15%. Possibly the belts from Kihnu to Värska and from Liepaja to Atašiene (Fig. 1) represent areas where the coastline stayed for a comparatively long time. Subangular-subrounded grains clearly prevail in the Vadja Fm. A higher content of rounded grains was recorded in the upper part of the Vadja Fm. in the southern region (Palanga, Skaune; Figs 3, 4). In most of the studied sections the degree of rounding is relatively high in the lower part of the Leivu Fm. (Figs 3, 4). This level is also characterized by an increased content of coarse clastic material in carbonate rock (Fig. 6D). In northern regions the basal part of the Leivu Fm., rich in clastic material, is thin (0.1–0.5 m; Tartu, Mehikoorma, Värska, and Tõlla cores) and falls partly in a local sedimentation break with a strongly eroded surface (Kleesment & Mark-Kurik 1997). In southern areas (Riešutyne, Remte, Liepaja, and Palanga cores) the respective interval is 20–30 m. The increased roundness of clastic material in the basal part of the Leivu Fm., expressed by a sharp peak in the roundness value in the Värska, Tsiistre, Baltinava, and

Uulu drill cores, is connected with repeated erosion, redeposition, and transport during the sedimentation break at the beginning of the Leivu Age in the northern region, marking here a subaerial unconformity (Kleesment & Mark-Kurik 1997). In the south the level with increased roundness becomes less clear (Remte and Liepaja cores) or is not seen at all (Palanga, Fig. 4). The rounded material was transported to the south where the sedimentation was continuous (Kuršs 1992). In the south the boundary of the Vadja and Leivu Fms marks a correlative conformity, while erosion-type unconformity occurs in the northern part of the study area. In the upper part of the Leivu Fm. the roundness of quartz particles is predominantly uniform (Figs 3, 4). The content of both – angular and rounded – quartz grains is usually less than 5%. Roundness values in the rocks of the Kernave Fm. are more variable (Figs 3, 4). The proportion of rounded particles in these beds may be up to 20%, while angular particles are lacking and in only rare cases reach up to 15%. The roundness of quartz grains of the Viljandi and Kureküla beds is similar. Rounded grains are more numerous in the upper parts of the studied sections, beginning with the upper part of the Aruküla Fm. (Tarvastu Beds) where subrounded grains clearly dominate (Fig. 5). The highest roundness of quartz grains was recorded in some interlayers of the Gauja Fm., marking the periods of repeated redeposition (Kleesment 2007).

Surface features of quartz grains

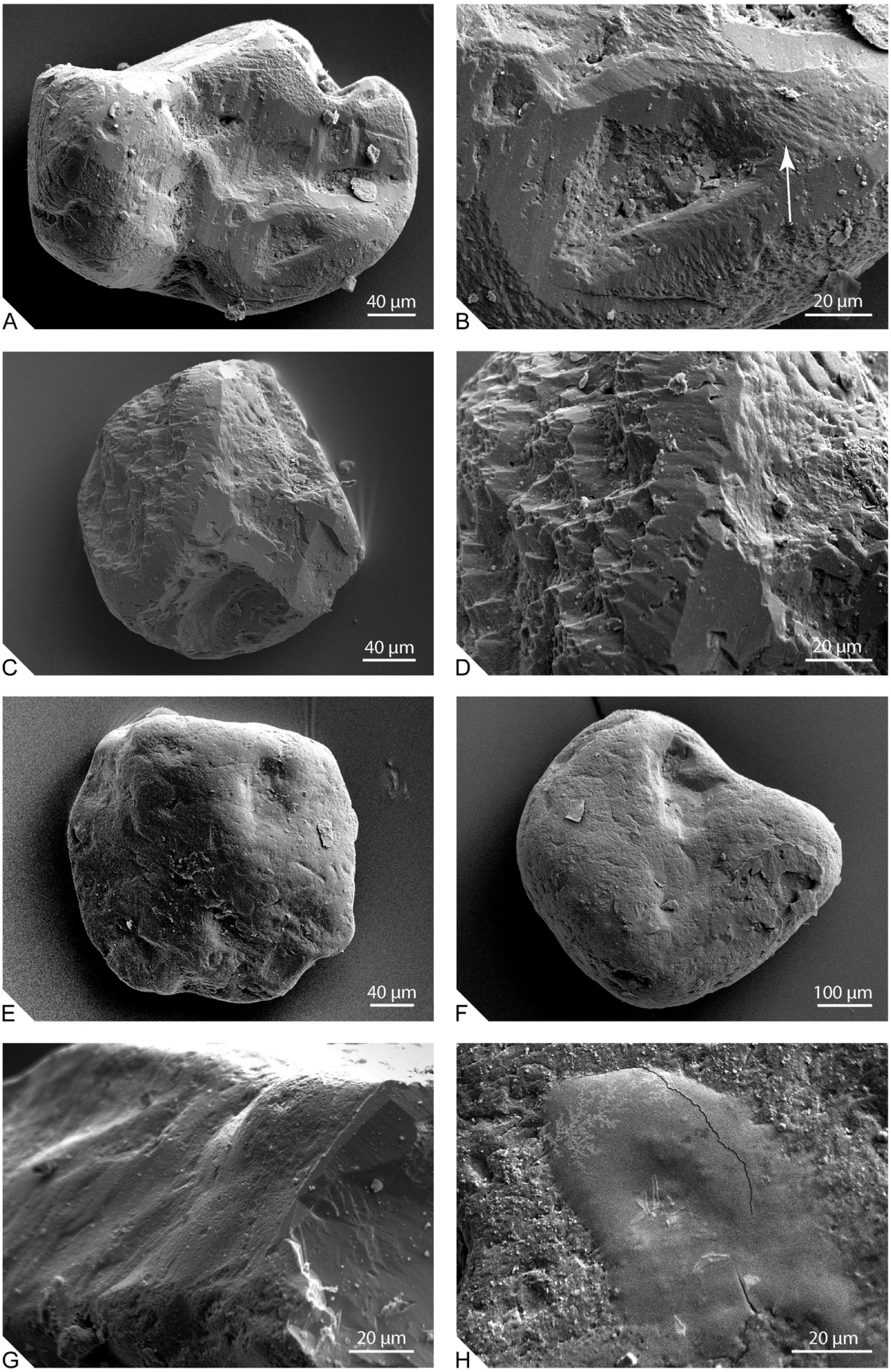
The surface textures of quartz grains observed under the SEM refer to various sedimentation environments. Diversity in surface textures exhibits variations at different stratigraphical levels. Quartz grains in Rezekne and Pärnu sandstones have low to medium relief with smoothed abrasion cavities (Fig. 7A, B, E, F) and conchoidal fractures (Fig. 7G). Irregular, rounded, curved, and V-shaped scratches are found (Fig. 7A–C, E, F, H). In some cases particles have indistinct platy structure (Fig. 7A, B, F). In drill cores where sandstone is intercalated by carbonate complexes, for example Kihnu and Kavastu sections, oriented etch pits indicate dissolution processes during postdepositional events (Fig. 7B, D). The Pärnu Fm. rocks of the Kihnu drill core display desiccation cracks in clayey coatings of quartz grains (Fig. 7H).

Roundness of quartz grains in dolomitic rocks of the Vadja and Leivu Fms differs from that of Rezekne–Pärnu rocks insignificantly (Figs 3, 4), but the surface microtextures are more different. Besides low and medium relief, grains of the Leivu Fm. often have high relief (Fig. 8A). Features derived from transport in water currents – cavities, V-shaped pits, and conchoidal fractures (Fig. 8A–E) – are characteristic of the Vadja and Leivu Fms. In some cases dense sets of V-shaped pits related to high-energy conditions are found (Fig. 8D). Solution pits are comparatively rare (Fig. 8E). The clayey coating of one quartz grain from the basal beds of the Leivu Fm. of the Drissa core bears desiccation cracks (Fig. 8F).

Quartz grains of siliciclastic rocks of the Kernave Fm. have an abraded surface with V-shaped, linear, and curved scratches, irregular pits and cavities (Fig. 9A–C). Subparallel and curved step-like features are derived from abrasion (Fig. 9A, B), but in some cases chemical etching has possibly caused the formation of a striated surface (Fig. 9C). Often oriented fine pits of chemical etching are found (Fig. 9B, C, upper plane). Etching features are more characteristic of quartz grains of the Aruküla Fm., which have mainly low to medium relief. Besides fresh abrasion pits and grooves on quartz particles (Fig. 9D–F) there occur abundant oriented etch pits (Fig. 9H), frequent polished and smoothed grains having a smoothed preliminary abraded surface (Fig. 9G), and relatively rare V-shaped abrasion pits (Fig. 8D). Grains have often platy structure with subparallel linear fractures (Fig. 9D, E, G). Mahaney & Kalm (2000) found only rare such grains, but other characteristics of surface textures described in that publication and in the present work are similar.

Quartz grains in sandstones of the Burtnieki and Gauja Fms contain more rounded particles than these of the lower units (Fig. 10A–F). Here the outer surface of the grain is usually rounded and smoothed, almost entirely bearing low relief with small mechanical abrasion features (Fig. 10A, C, E). Only some deep features are

Fig. 7. SEM microphotographs of quartz grains of siliciclastic rocks from the Rezekne and Pärnu Fms. **A**, subrounded grain exhibiting indistinct platy structure; smoothed irregular and V-shaped abrasion features; Pärnu Fm., Kavastu core, 105 m. **B**, enlarged detail of the same grain; in places small oriented etch pits are observed (indicated by the arrow). **C**, subrounded grain with oriented etch pits and a deep abrasion cavity in its lower part; Pärnu Fm., Kihnu core, 47 m. **D**, enlarged detail of the same grain with oriented etch pits. **E**, subrounded grain with smoothed abrasion features; Rezekne Fm., Kavastu core, 137 m. **F**, rounded grain exhibiting indistinct platy structure; curved and V-shaped abrasion features; Pärnu Fm., Kihnu core, 45 m. **G**, smoothed step-like conchoidal surface; Pärnu Fm., Kavastu core, 122 m. **H**, desiccation cracks in clayey coating; Pärnu Fm., Kihnu core, 45 m.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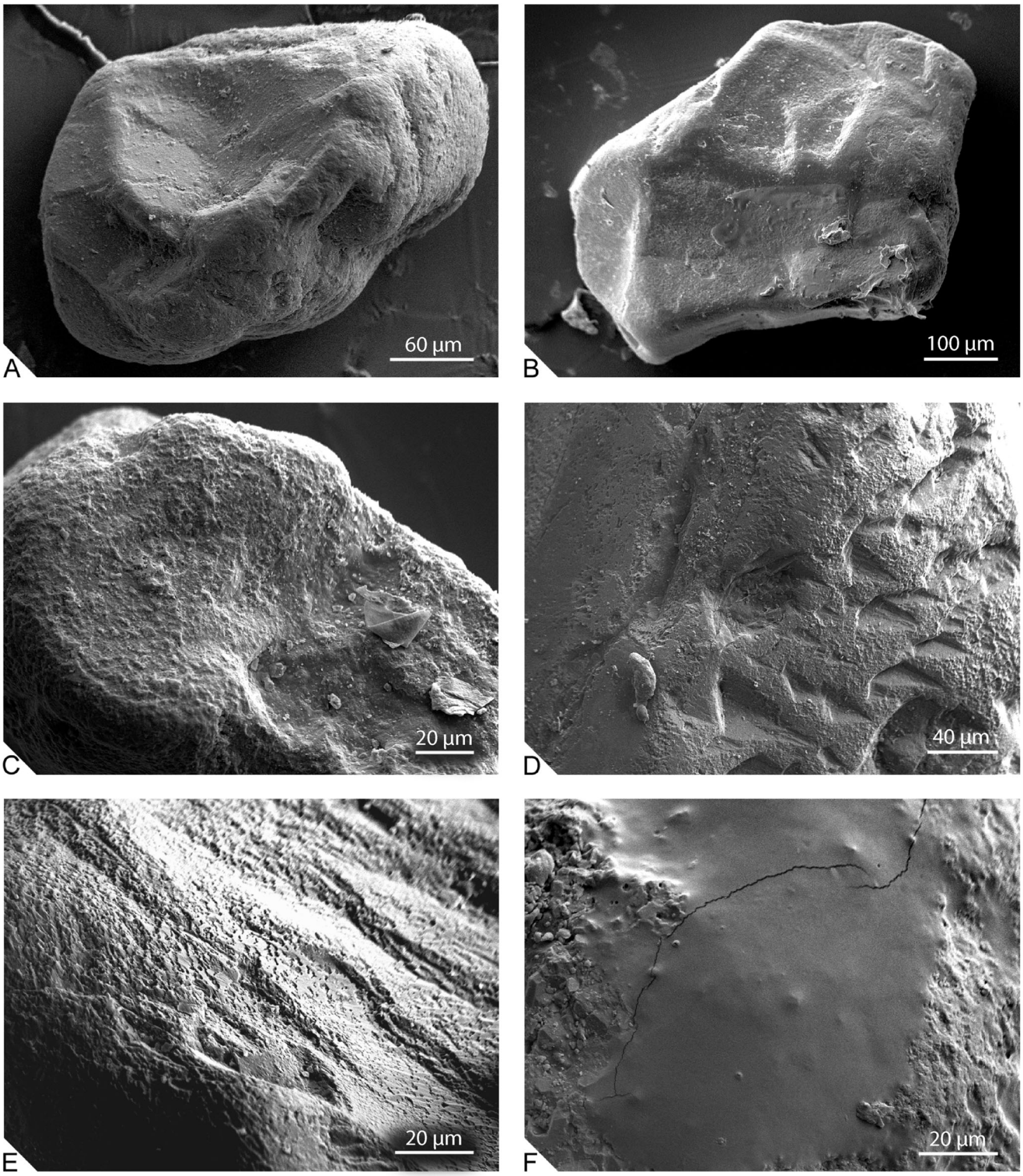
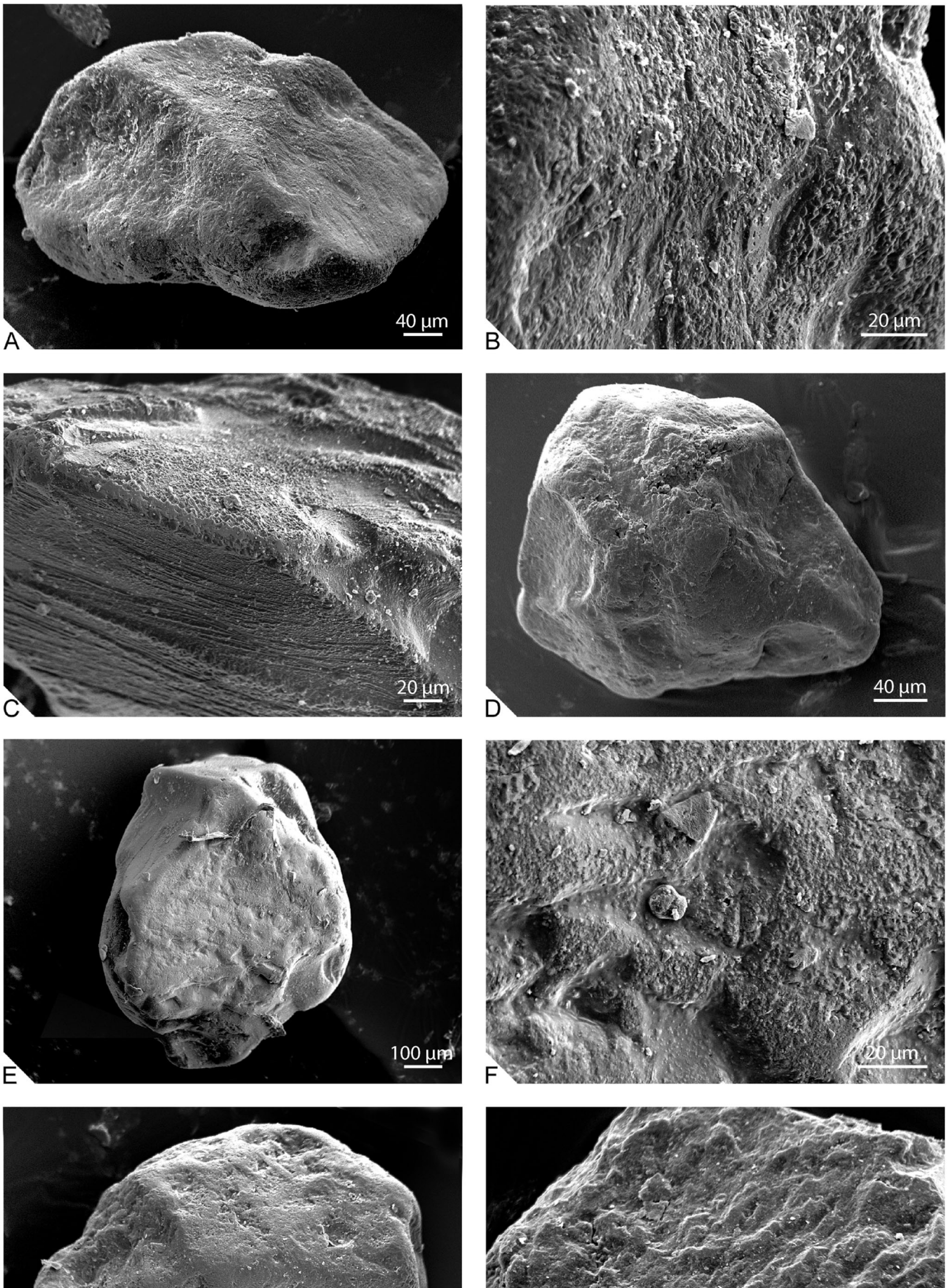


Fig. 8. SEM microphotographs of quartz grains from dolomite rocks of the Leivu Fm. **A**, fresh large abrasion pits and parallel thin straight scratches (on top and on the right); Drissa core, 269 m. **B**, subangular grain with smoothed angular large pits on the surface; Riešutyne core, 238 m. **C**, subrounded grain with a large abrasion groove with irregular outline at the base; Skaune core, 240 m. **D**, quartz surface with abundant fresh V-shaped, triangular, curved, and straight scratches; Slantsy core, 120 m. **E**, grain surface with subparallel steps, covered with small rhombohedron-shaped dissolution pits; Slantsy core, 120 m. **F**, desiccation cracks in clayey coating; Drissa core, 269 m.

Fig. 9. SEM microphotographs of quartz grains of siliciclastic rocks from the Kernave and Aruküla Fms. **A**, fresh abrasion grooves and scratches (upper surface plane); Kernave Fm., Tõrva core, 140 m. **B**, Enlarged detail of the same grain; straight and curved abrasion scratches; surface is pitted due to dissolution. **C**, grain with straight and V-shaped abrasion grooves in the upper surface plane and fine subparallel dissolution (?) features on the lateral side; Kernave Fm., Tõrva core, 140 m. **D**, indistinctly platy grain with abrasion grooves and V-shaped pits; Tarvastu Mill outcrop, Aruküla Fm., Tarvastu Beds. **E**, indistinct platy grain with partly smoothed abrasion grooves; Kallaste outcrop, Aruküla Fm., Kureküla Beds. **F**, enlarged detail of the same grain; fresh V-shaped pits are observable. **G**, indistinct platy grain with smoothed surface and abrasion features; Tartu Cemetery outcrop, Aruküla Fm., Viljandi Beds. **H**, oriented dissolution pits on the upper surface; Tartu Cemetery outcrop, Aruküla Fm., Viljandi Beds.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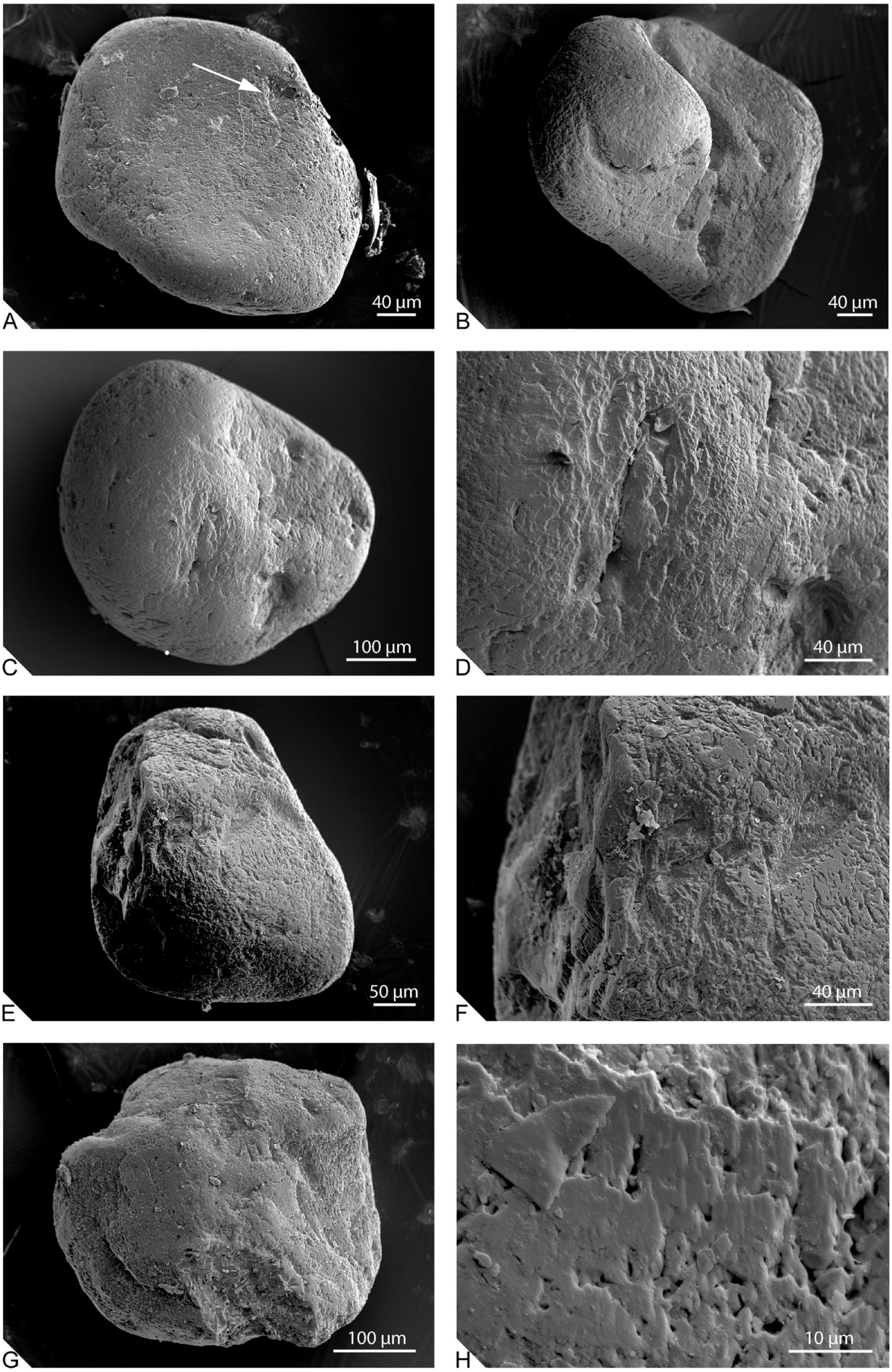
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survived from previous high abrasional relief (Fig. 10B, E, F). In addition, there occur rare obliterated V-shaped pits (Fig. 10A), a few small dissolution pits (Fig. 10D, H), and high outer relief and fresh abrasion grooves (Fig. 10G). Frequent sets of parallel microfractures are observed, however, they are usually obliterated (Fig. 10B–G).

Quartz grains of the studied Devonian rocks have predominantly mechanical surface texture. Fresh abrasion features are common in carbonate rocks, showing rapid deposition of detrital material (Fig. 8A–D). Subparallel linear fracture sets are found in all levels, while sub-parallel steps similar to conchoidal surfaces are present only on the grains of the Pärnu and Leivu Fms (Figs 7G, 8E). The dissolution features are more numerous in the Kernave Fm. and lower part of the Aruküla Fm. where dolomitic and siliciclastic rocks intercalate. Chemical etching features have probably formed during diagenesis. Strongly smoothed rounded grains with masked preliminary relief are mainly present in siliciclastic complexes of the Burtnieki and Gauja Fms, referring to intensive and multiple reworking and redepositional processes (Fig. 10). Obliterated grains occur also in some levels of the Pärnu Fm. (Fig. 7E, F).

DISCUSSION

Together with information on the distribution of lithological (Kuršs 1992) and mineralogical (Kleesment & Kuršs 1977) units in the East Baltic area and on the structures of rock complexes (Ponten & Plink-Björklund 2007), data on the roundness and surface textures of quartz grains, and the spatial and vertical variability of these features in a section help to clarify events in basin evolution. In most part of the observed sequence moderately spherical subangular to subrounded quartz grains predominate, possibly largely due to the original outline of the grains in source rock and partly to the moderate distance of transportation (Plink-Björklund & Björklund 1999). This indicates that a significant proportion of the material has deposited during the first cycle of sedimentation. The abundance of rounded grains (30–60%) in the upper part of the examined sequence, especially in the Burtnieki and Gauja Fms, which have also been distinguished by high mineral maturity of sediments (Kleesment 1995, 2007), indicate repeated redeposition of sediments. Local abundance of rounded quartz grains (25–35%) in the boundary beds of the Vadja and Leivu Fms and in some levels of the Pärnu and Rezekne Fms suggests that grains originate largely from the recycling of sediments (Figs 3, 4). Considerable variations in grain roundness in the Rezekne and Pärnu Fms reflect changes in the depositional environment. The belts of sediments with increased roundness of quartz grains, extending from Kihnu to Värska and from Liepaja to Atašiene, in all likelihood mark positions of ancient coastlines. The levels of increased roundness in the Pärnu section refer to local sedimentation breaks and alternation of intensive erosion and influx-dominated periods. This conclusion is also confirmed by other lithological and structural data (Kleesment 1997; Tovmasyan et al. 2008). An additional proof of the occurrence of sedimentation breaks is desiccation cracks in the clay coating of a quartz grain from the Pärnu Fm. of the Kihnu drill core (Fig. 7H), which was possibly formed during the insolation (Molnár et al. 1995). Cracks in the clay coating occur also in the basal beds of the Leivu Fm. in the Drissa borehole (Fig. 8F), in the level corresponding to an essential sedimentation break in the northern region of the studied Devonian basin (Kleesment 1997; Kleesment & Mark-Kurik 1997). The Drissa borehole is located in the region of probable continuous sedimentation during the Narva Age (Kuršs 1992; Valiukevičius et al. 1986; Kleesment 1997). On the other hand, grains with desiccation cracks in the clay coating must be deposited in situ as during transport these features should have been obliterated. The occurrence of a local sedimentation break in this region has to be proved by further investigations.

Examination of the surface textures of quartz grains revealed the domination of features indicating transport in water environment. In the studied sequence abundant abrasion features like V-shaped pits, and linear and curved grooves usually give evidence of transport in a fluvial medium and are probably caused by gouging

Fig. 10. SEM microphotographs of quartz grains of siliciclastic rocks from the Burtnieki and Gauja Fms. **A**, rounded and obliterated grain with some small abrasion features; V-shaped embayment (indicated by the arrow) in the upper part; Koorküla outcrop, Burtnieki Fm., Koorküla Beds. **B**, rounded and smoothed grain with linear trough and some irregular and curved abrasion features; Suur-Ütsealutse outcrop, Burtnieki Fm., Abava Beds. **C**, rounded and smoothed grain with subparallel linear fractions in the middle part and some low abrasion pits; Keldri outcrop, Gauja Fm., Lode Member. **D**, enlarged detail of the same grain showing the fracture set and small etching features. **E**, rounded and smoothed grain with subparallel linear fractures; Arstle outcrop, Burtnieki Fm., Härma Beds. **F**, enlarged detail of the same grain showing linear troughs along the fracture set (on the left). **G**, subrounded grain with fresh abrasion grooves and subparallel fractures; Koorküla outcrop, Burtnieki Fm., Koorküla Beds. **H**, quartz grain surface with dissolution pits; Hinni outcrop, Gauja Fm., Sietini Member.

when one grain strikes another; however, these features occur also in beach sands (Kasper-Zubillaga et al. 2005). V-shaped pits are often abundant in the marine environment, but seldom found in deltaic conditions (Madhavaraju et al. 2006). Subparallel linear fracture sets (Figs 7E; 10C–G) as well are mostly related to abrasion during transport in water, while conchoidal surfaces and cavities (Figs 7C, G; 8A, C; 9E) refer to high-energy aquatic transport (Cherian et al. 2004). Afterwards sediment reworking in the beach environment took place and the surf action increased grain roundness. Surf action was particularly strong in some episodes of Rezekne and Pärnu times, but especially in Burtnieki and Gauja times. Samples of Pärnu time yielded grains with conchoidal fractures and deep grooves indicative of high-energy water transport (Fig. 7C, G). Grains of the Burtnieki and Gauja sections are highly smoothed and obliterated (Figs 7E, F; 10A–C), whereas only some deep grooves are survived from high abrasion relief (Fig. 10G). In earlier works Pärnu and Gauja deposits are considered as tide-influenced delta sediments (Ponten & Plink-Björklund 2007; Tovmasyan et al. 2008). However, the grain morphology and lithological character of sections (Märss et al. 2008) show that delta deposition alternated with beach conditions and breaks in sedimentation. In the studied sections levels with smoothed and rounded grains alternate with levels dominated by subangular particles.

Dissolution features are more abundant in sandstones of the Pärnu, Kernava, and Aruküla Fms. These are represented by intercalation of siliciclastic and carbonate beds and are, probably, of diagenetic origin (Burley & Worden 2003; Walderhaug et al. 2006). Etching and dissolution features in deposits of the Gauja and Burtnieki Fms possibly result from the weathering of the Devonian soil profiles formed. The surface textures found here (Fig. 10D, H) are similar to subaerial weathering features described in Okhravi & Amini (2001) and Kasper-Zubillaga et al. (2005), indicating the existence of subaerial conditions in these times. Some dissolution features, found in carbonate rocks of the Leivu Fm. (Fig. 8E), may have developed due to chemical solution activity of seawater under alkaline conditions (Cherian et al. 2004). However, it must be mentioned that surface textures alone cannot determine unequivocally the environment of deposition of quartz sand grains because abrasion in different depositional environments can produce highly similar surface textures (Mazzullo et al. 1986). For instance, subparallel fracture sets of mechanical origin are sometimes hard to discriminate from striation textures (Fig. 9C) caused by chemical solution (Mazzullo et al. 1986; Newsome & Ladd 1999; Cherian et al. 2004).

SUMMARY AND CONCLUSIONS

Up to the end of the 20th century the evolution of the Devonian Baltic basin was reconstructed mainly on the basis of macrolithological data (Kuršs 1992; Kleesment 1997; Plink-Björklund & Björklund 1999). Later detailed sedimentological and facies analyses of the Pärnu, Narva, and Gauja levels have been carried out and the coastline position and direction of currents have been established (Ponten & Plink-Björklund 2007; Tovmasyan et al. 2008; Tänavsuu-Milkeviciene et al. 2008). The spatial and temporal distribution pattern of the roundness of quartz particles contained in the studied Devonian sedimentary rocks revealed some clear trends in the Baltic basin and contributes to the estimation of basin evolution and the palaeogeographical situation. The following conclusions can be drawn.

1. The basal part of the Leivu Fm. in the north of the study area is characterized by a high degree of rounding of particles referring to redeposition of quartz grains and thus may serve as a good correlative level.
2. Great variation in the roundness of quartz grains in the sections of the Pärnu and Gauja Fms indicates alternation of episodes of intensive erosion and influx-dominated periods connected with shift of the shoreline.
3. Mechanical features dominate among surface textures of quartz grains, indicating transport in high-energy water environment; beach features are found in the Pärnu, Aruküla, and Gauja Fms.
4. Dissolution etch pits of diagenetic origin are more abundant in Devonian sandstones intercalating with carbonate layers.

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Kvartsterade ümardatus ja pealispinna reljeef Põhja-Baltikumi Devoni kivimites ning nende paleogeograafiline tähtsus

Anne Kleesment

Kvartsterade ümardatust ja pealispinna reljeefi uuriti Põhja-Baltikumi 32 puursüdamiku baasil. Ümardatust määrati rohkem kui 800 proovis ja 70 tera pealispinna iseloomu uuriti skaneerivas elektronmikroskoobis. Tehti kindlaks ümardatuse muutuse vertikaalsed ja horisontaalsed seaduspärasused. Kõrgenenud ümardatus Pärnu kihistu mõnes tasemes, Leivu kihistu basaalsetes kihtides ja läbilõike ülemises osas viitavad materjali ümbersettimise protsessidele nendes tasemetes. Ka kvartsi pealispinna ehituses ilmnevad läbilõikes teatud seaduspärasused: valdavad on mehaanilise abrasiooni vormid, eelkõige V-kujulised augud ja sirged ning kõverad süvendid, mille teket seostatakse voolava vee keskkonnaga. Tasemetes, kus on toimunud materjali intensiivne ümbersettimine, kannavad terade pinnavormid selgeid kulutuse tunnuseid. Keemilise söövituse vorme esineb rohkem Pärnu, Kernave ja Aruküla kihistus, kus läbilõikes vahelduvad purd- ning karbonaatsed kivimid. Tõenäolisi Devoni-aegsete pinnasekihtidega seotud söövitusvorme on registreeritud läbilõike ülemises osas. Purdterade ümardatuse ja pinna ehituse andmed aitavad selgitada basseini arengut ning määrata settelünkade olemasolu.