



Multi-stage development of Cambrian sedimentary dykes in the Paleoproterozoic granites from the Västervik area (SE Sweden): evidence from macro and microfabrics

N. FRIESE^{1*}, A. VOLLBRECHT¹, B. LEISS¹ AND O. JACKE¹

¹Geoscience Centre Goettingen, Georg-August University of Goettingen, Goldschmidstrasse 3, D-37077 Goettingen, Germany.

*e-mail: nfriese@gwdg.de

Abstract: Micro and macrofabrics of Cambrian sedimentary dykes formed in Paleoproterozoic granites of the Västervik area in SE Sweden give evidence that periods of dyke formation under tensional stress alternated with periods of compression normal to the dyke walls. Sagging structures together with the preferred orientation of compositional boundaries and long axes of grains/rock fragments parallel to the dyke walls are interpreted as the result of subsidence-controlled flow of unconsolidated fillings during episodes of downward dyke growth.

Keywords: Cambrian, sedimentary dykes, polyphase formation, SE Sweden, microfabrics, macrofabrics.

Sedimentary dykes in crystalline basement rocks have been described from different areas of the Baltic shield (Carlson and Holmquist, 1968; Bergman, 1982; Katzung and Obst, 1997). They have been interpreted to be of Cambrian age although only a few fillings could be dated by fossils giving the maximum age of fissure formation (Tynni, 1982).

Up to now, comprehensive fabric analyses providing more detailed information about the evolutionary history of these sedimentary dykes are rare. This study focuses on macro and microfabrics of sedimentary dykes in the Proterozoic basement of the Västervik area (Figs. 1a and 1b) and relates their origin to the Cambrian geodynamics of SE Sweden. The dykes are N-S- and NE-SW-striking (Fig. 1b) and up to 10 cm wide (Figs. 1c and 1d). Samples for the present study were collected from a road cut at the highway E22 approximately 2.5 km north of the village Gunnebo (Figs. 1b and 1c).

The Västervik area belongs to the transition zone between the Svecofennian domain to the north and the Trans-Scandinavian Igneous Belt to the south (TIB) (Fig. 1a), which is related to an E- to NE-dipping Paleoproterozoic subduction zone within the Baltic Shield (Beunk and Page, 2001). The metasediments (Fig. 1b) of the so-called Västervik formation are related to a back-arc basin filled between 1.88-1.85 Ga (Sultan *et al.*, 2005). Shortly after deposition, the Västervik formation was strongly deformed in a transpressional regime under High-T/Low-P conditions and subsequently intruded by various generations of granitoids (Fig. 1b), between 1.85 and 1.65 Ga. (Åhäll and Larson, 2000). Due to extensive lithospheric uplift and erosion during the late Proterozoic and probably Early Cambrian, this basement was deeply eroded and subsequently covered by Lower Paleozoic platform sediments of several hundreds of meters in thickness. This cover was eroded even lower than the Cambrian unconformity mainly during the Mesozoic

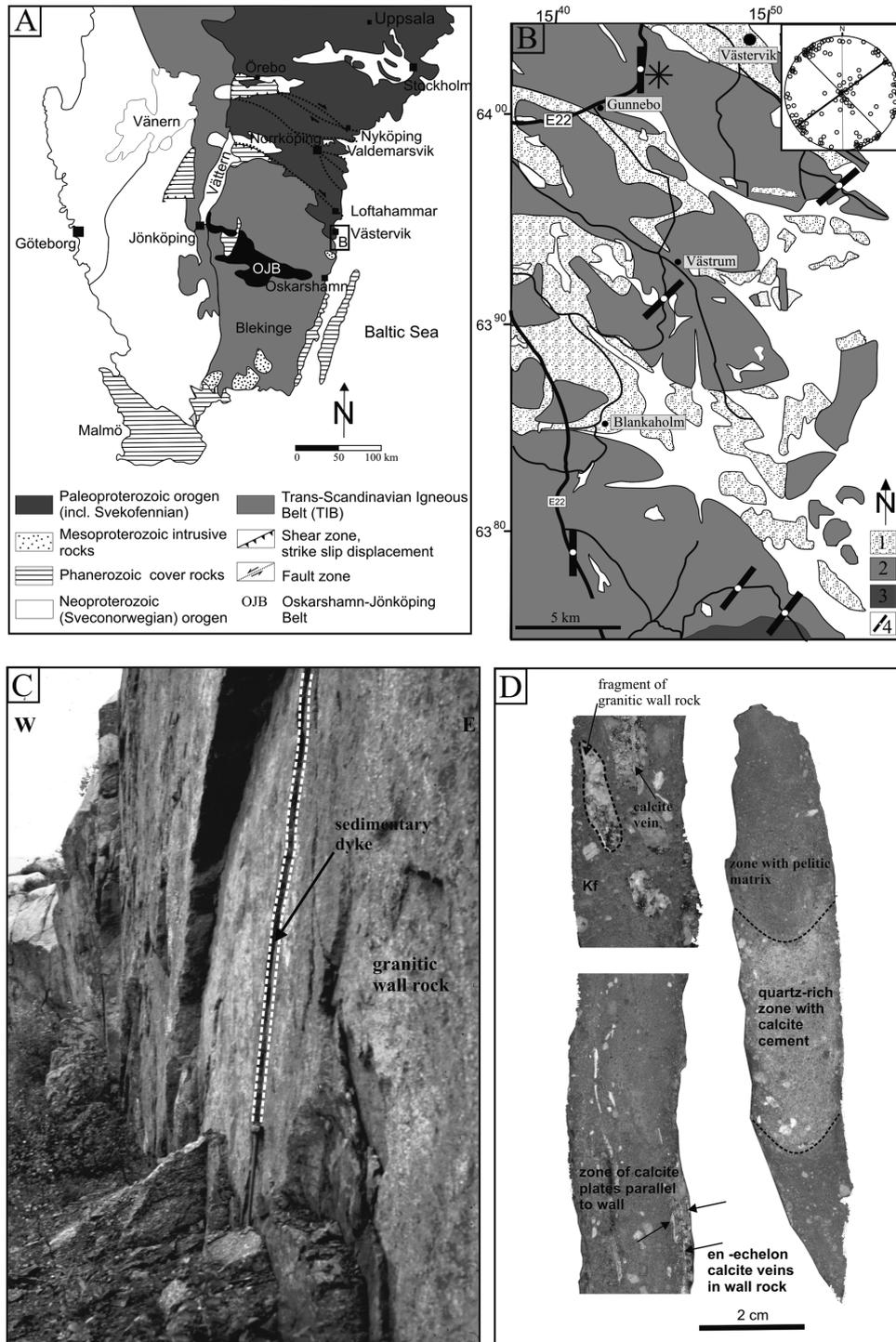


Figure 1. (A) Simplified geological map of South Sweden (modified after Beunk and Page, 2001). Location in (B) is marked, (B) simplified geological map of the Västervik area including the occurrence of sedimentary dykes after Lundegårdh *et al.* (1985) and Carlson and Holmquist (1968). 1: Metasediments; 2: Granites; 3: Götemar Granite; 4: Sedimentary dyke. Plot of maxima in strike trends of joints in granites shown as circles (source: 40 diploma mapping projects in the Västervik area by University of Goettingen, Germany). Lines in diagram indicate the predominant striking trend of steeply dipping joints. Location of the studied sedimentary dyke near Gunnebo is indicated by a star, (C) outcrop east of the road E22 showing the studied sedimentary dyke (dashed white line); hammer for scale. View north, (D) macrofabrics of the sedimentary dyke near Gunnebo. Hand specimen (upper left) shows granitic fragments and potassium feldspars (Kf) aligned to dyke wall; (lower left) calcite veins in the dyke; (right) generations of dyke fillings – top and bottom: domain rich in pelitic material, central segment: quartz-rich zone with calcite cement, convex arcs pointing downwards.

and Quaternary, so that the Cambrian sedimentary dykes became exposed.

Results from macro and microfacies

Macrofabrics

Dyke filling contacts with the granitic wall rock are sharp and planar. The dyke filling consists of layers of sandstone with well-rounded quartz grains alternating with bands of sandy pelites (Fig. 1d). Some sections of the dyke contain narrow bands parallel to the dyke walls, which are composed of angular granitic rock fragments from the host rock and greyish platy carbonate grains with their long axis sub-parallel to the dyke boundaries (Fig. 1d).

Microfabrics – Detrital components

The psammitic components are dominated by well-rounded monocrystalline quartz grains. The grains are mostly of plutonic type (dark blue cathodoluminescence colours, CL) and lack intragranular deformation structures. Potassium feldspars are less common, but larger in size, and often display hypidiomorphic shape with thin perthitic exsolution lamellae and diagenetic overgrowth zones. Microcline is abundant with typical cross twinning, showing only minor alteration in contrast to plagioclase grains that are often strongly altered to sericite. Conspicuous platy grains of calcite are interpreted as fragments of microveins which were mixed with the siliciclastic material during later dyke opening/filling steps.

Microfabrics – In situ-formed fabrics and mineralizations

In domains poor in pelitic matrix, mechanical compaction by grain rotation associated with micro-breciation is one of the early processes, together with pressure solution of quartz. In primarily more porous fabric domains, mechanical compaction was limited by early calcite cementation, shown by the predominance of point contacts between quartz grains.

Calcite also precipitated in small scale fractures forming microveins. These fractures formed in already lithified domains of the clastic dykes. This is evident from the fact that vein propagation occurred not only along grain boundaries but also transgranular, i.e. by cutting detrital grains of quartz and feldspar. The distinct growth zonation shown by alternating CL colours indicates a cyclic variation in fluid influx during calcite cementation and that this mineralisation occurred into open fissures. CL images reveal contin-

uous transitions between calcite microveins and calcitic matrix pointing to a common event and that the microveins formed by repeated crack-sealing. During subsequent dyke opening and filling these microveins were disrupted and incorporated as platy fragments into the clastic material.

The different microfabric domains display a heterogeneous distribution which may result from primarily variations in composition and porosity, spatiotemporally variations in flow of different pore fluids and local stress variations. Hence, a complete sequence of the dyke (formation and) filling processes cannot be clearly reconstructed because unambiguous age relationships have only been established for restricted fabric domains and might not be valid for the whole dyke fills. This may be due to repeated events with spatial and temporal overlaps.

Discussion

The sedimentary dykes probably formed already in Early-Cambrian or even Precambrian times. According to their strike directions, the dyke formation can be related to a NE-SW directed rifting along the south western margin of Baltica during Early to Middle Cambrian, representing the latest stages of the Precambrian super continent break-up (Hartz and Torsvik, 2002; Cocks and Torsvik, 2005). The development of two sets of dykes was controlled by pre-existing subvertical joint sets oriented at high angle to the extension direction. Based on the predominance of well-rounded quartz grains, the formation of the sedimentary dykes can be attributed to an inshore environment, which agrees with the paleogeographic reconstruction of Hagenfeldt (1989).

The following stages describe a sequence of events which may have been passed through several times until individual dykes attained their final dimensions. (1) Initial formation of subvertical tension cracks/fractures. (2) Lateral extension and downward propagation of fracture. Simultaneous filling with wall rock fragments, detrital grains, and mud supplied from the surface. (3) Further fracture extension caused a sagging effect leading to a downward dragging of the unconsolidated fillings, and reorientation of elongated components. (4) Consolidation of fracture fillings due to combined pure mechanical compaction, horizontal compression, pressure solution and precipitation of quartz or authigenesis of chlorite and pyrite. (5) Formation of calcite microveins by calcite cementation in fractures cut in an already lithified dyke filling and the adjacent wall rock. Quartz cement and detrital quartz were partly replaced

by calcite. (6) Phase of dyke opening with transection of already lithified sediments. Epiclastic sediments incorporated clasts of the partly brecciated indurated sediments together with platy fragments of the calcite veins. (7) Progressive downward dyke propagation and related subsidence of the latest sediment fillings.

Conclusions

A closer look to the macro and microfabrics of sedimentary dykes has revealed a polyphase origin due to repeated fracture propagation under varying conditions. This may also imply that dyke formation lasted over a long time span with alternating periods of opening/filling, cementation/lithification and alteration. There is no clear evidence of a forceful opening and filling due to hydraulic overpressures. The concave-upwards internal structure of

the sedimentary dykes is characteristic for a passive gravitational infill from the surface, rather than by injection under high fluid pressure. Arrangements of elongate grains parallel to the dyke walls are interpreted to represent flow fabrics that develop by subsidence of unconsolidated sediments during downward dyke propagation. Pressure solution of quartz gives evidence that extensional phases with dyke propagation were interrupted by phases of compression. The strike of the sedimentary dykes can be correlated to the NE-SW oriented rifting at Cambrian time.

Acknowledgements

Thanks are due to colleagues of Geoscience Centre Goettingen for intensive discussions. Luis Pedro Fernández is acknowledged for helpful comments that improved the manuscript.

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