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Basaltic Dykes in the Kap Washington and Frigg Fjord Areas (North Greenland)

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THEME 1: Magmatic Provinces around the Eurasian Basin – Interplay with Tectonism

Summary: Basaltic dykes cutting Lower Paleozoic to Upper Cretaceous sediments in the area around the volcanic Kap Washington Group, and in the Harder Fjord fault zone around Frigg Fjord in North Greenland, were studied during the BGR CASE 2 expedition in 1994. There are no significant petrological or geochemical differences between the dykes at different stratigraphic levels. Geochemically, all dyke rocks are comparable with intraplate alkaline basalts. Their similar chemical composition and sparse stratigraphic evidence suggest that the dykes have more or less the same age as the basalts of the Kap Washington Group (Late Cretaceous to Early Tertiary).

The so-called „greenstones of unknown age" in the western Frigg Fjord segment of the Harder Fjord fault zone are interpreted as relics of E–W trending dykes which were strongly fractured during subsequent compressive deformation.

INTRODUCTION

The volcanic suite of the Upper Cretaceous/Lower Tertiary Kap Washington Group (KWG) on the north coast of Greenland is associated with a dense swarm of basaltic dykes trending mainly N–S (DAWES & SOPER 1970, HIGGINS et al. 1981) (Fig. 1). Cambrian sediments deformed and metamorphosed during the Ellesmerian (predominantly Devonian) orogeny are thrust from the south onto the KWG along the Kap Cannon thrust zone. The dykes cut Lower Paleozoic metasediments of the Ellesmerian North Greenland fold belt to the south and southwest of the KWG (between latitudes 38 °W and 48 °W) and post-orogenic Permo-Carboniferous and Cretaceous sediments beneath the Kap Washington Group (HÅKANSSON et al. 1981, BROWN & PARSONS 1981, BROWN et al. 1987). No dykes were observed actually cutting the thrust zone between the Ellesmerian basement and the volcanic suite of the KWG, but the KWG itself contains basaltic and rhyolitic dykes.

The dyke swarm continues to the SE towards the Frigg Fjord area, where the dykes are less abundant (Fig. 1). South of the Harder Fjord fault zone (HFFZ), the dykes trend mainly W to NW (HIGGINS et al. 1981, SOPER & HIGGINS 1991, HENRIKSEN 1992).

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The following subvolcanic rocks were investigated in 1994 during the BGR CASE 2 expediton (Fig.1):

- in the Kap Washington area
  - dykes in Lower Paleozoic sediments on the islands to the west of Lockwood Ø and on the SW part of Lockwood Ø near the thrust zone,
  - dykes in Permian sediments on the NW part of Lockwood Ø,
- in the HFFZ around Frigg Fjord
  - dykes in Lower Paleozoic sediments,
  - so-called „greenstones of unknown age" (HIGGINS et al. 1981, GGU 1992),
  - dykes and sills in Upper Cretaceous (Santonian) sediments.

Chemical analyses were carried out in the BGR laboratories, Hannover. The detailed XRF whole-rock analyses are available from the author on request. Rb-Sr and Sm-Nd isotopic data on the dykes is given in ESTRADA et al. (in press).

DYKES IN THE KAP WASHINGTON AREA

Dykes in Lower Paleozoic sediments

Intensely sheared and boudinaged basaltic dykes occur in interbedded Cambrian limestones and shales on Lockwood Ø immediately south of the Kap Cannon thrust zone, along which the Ellesmerian basement has been thrust over the Kap Washington Group. The dyke rocks are metamorphosed to amphibolites, the primary clinopyroxene being replaced nearly completely by brown amphibole. Other secondary minerals in smaller amounts include carbonate, biotite, actinolite, chlorite, sericite, epidote and pumpellyite.

On the islands west of Lockwood Ø, the Cambrian basement is cut by numerous, mainly N–S trending dykes (Fig. 1). The dykes which were investigated on Luigi Amadeo Ø, Hazen Land and Inge Ø are also partly affected by alteration related to the Eurekan Kap Cannon thrust zone. On the southeastern tip of Luigi Amadeo Ø, the dykes are a few centimetres to 3 m thick. A folded dyke 30 cm thick was seen to be cut by a 3 cm thick dyke. The dyke rocks are intergranular dolerites and porphyritic basalts consisting of plagioclase, partly altered light brownish clinopyroxene, altered olivine, magnetite and accessory apatite as primary minerals, and with small amounts of secondary minerals such as biotite, brown and green amphibole, chlorite, carbonate, epidote and sericite. The partly porphyritic dolerites,

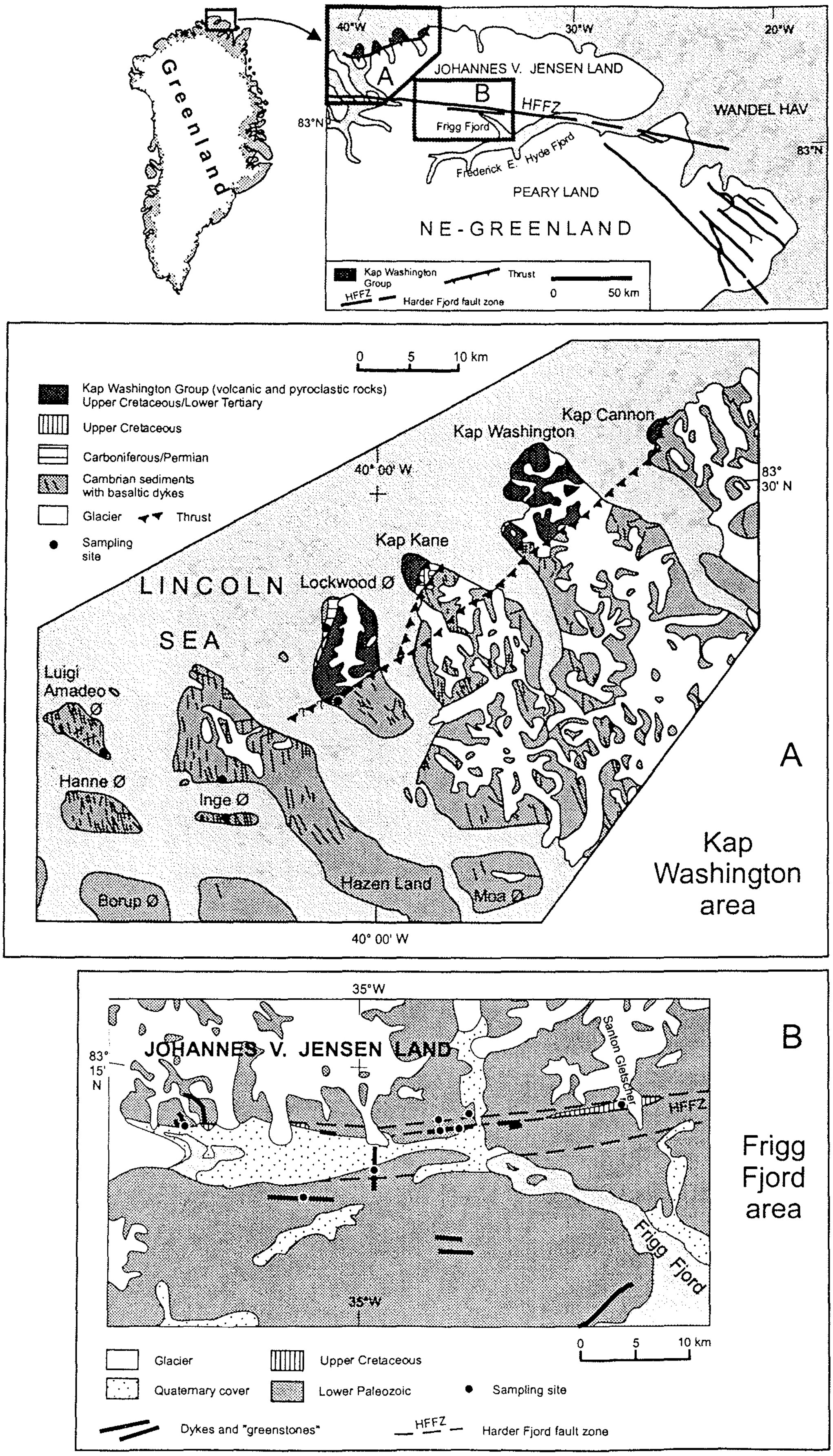

Fig. 1: Simplified geological maps of the study areas in North Greenland showing the sampling sites (based on Geological map of Greenland 1 : 500 000, sheets 7 and 8, GGU 1992, and on field observations during CASE 2); map A: Kap Washington area, map B: Frigg Fjord area.

which are several metres thick, from Hazen Land and Inge Ø are more strongly altered. The primary mineral composition is preserved only as relics, and secondary minerals (mentioned above) form most of the groundmass.

Dykes in Permian sediments

Irregular basaltic dykes cut Permian sediments on the NW coast of Lockwood Ø. They amount to more than one third of the width of the outcrop and individual dykes reach at least 100 m in thickness (HÅKANSSON et al. 1981). The dyke rocks are ophitic and intergranular dolerites with a primary mineral composition of plagioclase, light brownish clinopyroxene, altered olivine, magnetite and apatite. Locally, the dykes are fractured and intensely altered, with secondary minerals such as amphibole, chlorite, biotite, carbonate, pumpellyite and sericite. Some dykes are cut by thin porphyritic basaltic and microgranitic veins.

DYKES IN THE FRIGG FJORD AREA

Dykes in Lower Paleozoic sediments

Two long dykes, one N–S and the other E–W trending, which are not shown on the geological map (GGU 1992), occur west of Frigg Fjord and south of the HFFZ. The N–S dyke is about 2-3 m thick and is locally displaced by shearing. Fresh olivine is still preserved in this subophitic dolerite. The E-W dyke is about 2 m thick. The intergranular to subophitic dolerite is strongly altered. Secondary minerals such as biotite, amphibole, chlorite, carbonate can be observed.

Some other NW–SE, NE–SW and E–W trending dykes were sampled immediately north of the HFFZ. They are mainly intergranular to subophitic, partly porphyritic dolerites. Some dykes a few centimetres thick occur; these are porphyritic basalts with phenocrysts of plagioclase, light-brownish clinopyroxene and altered olivine.

„Greenstones"

Survey maps and early descriptions record „greenstones of unknown age" (HIGGINS et al. 1981, GGU 1992) in isolated outcrops within the HFFZ. DAWES & SOPER (1970) also note „an E–W dyke swarm north of Frigg Fjord"

Some of the rock units mapped as „greenstones" were systematically sampled northwest of Frigg Fjord. The rocks proved to be dolerites with subophitic and intergranular textures. They are locally intensely fractured and display slickensides. Features suggesting a subaqueous extrusion origin that were recorded farther east in the HFFZ (SOPER et al. 1982, SOPER & HIGGINS 1991) were not observed. In spite of the intense mechanical fragmentation, the primary mineral composition of clinopyroxene, plagioclase, invariably altered olivine, magnetite, and accessory apatite is still preserved. Secondary minerals such as sericite, chlorite, biotite, green and brown amphibole, carbonate, leucoxene, epidote and pumpellyite are always present in minor quantities (autohydrothermal alteration).

Dykes and sills near „Santon Gletscher"

Dykes and sills intrude a 400 m thick sequence of Upper Cretaceous (partly Upper Santonian) marine clastic sediments (HÅKANSSON et al. 1981, 1994) within the HFFZ on the west side of „Santon Gletscher" (Fig. 1). Subsequent compressive tectonism in early Tertiary time led to steepening (subvertical to overturned) of the whole unit (PIEPJOHN & GOSEN 1998) and related shearing of the dykes.

The dykes are relatively thin (20 cm to 1.5 m thick) and strike about N–S. Apophyses of one dyke form sills in white sandstones with conglomeratic intercalations and a 70 cm thick sill has caused local contact metamorphism of the sandstone. Nearby, a fractured and slickensided sill was observed to be cut by a N–S trending dyke 1.5 m thick.

Petrographically, there is no difference between the dykes and sills. The rocks vary from dolerite with intergranular and subophitic textures to very fine-grained, porphyritic basalt. The phenocrysts are plagioclase, light-brownish clinopyroxene and completely altered olivine. Secondary minerals are present in small amounts and include carbonate, chlorite, biotite, amphibole, sericite, leucoxene and quartz.

GEOCHEMISTRY

The dyke rocks plot mainly in the basalt and tephrite/basanite fields in the (Na_2O+K_2O) vs. SiO_2 diagram of LE MAITRE (1989) (Fig. 2). Their alkaline character is indicated by Nb/Y ratios >0.67 for most samples (Fig. 3) and a vertical trend in the TiO_2 vs. Zr/P_2O_5 diagram of FLOYD & WINCHESTER (1975). In all discrimination diagrams (Figs. 2–5) the field of the Kap Washington Group basalts is shown for comparison.

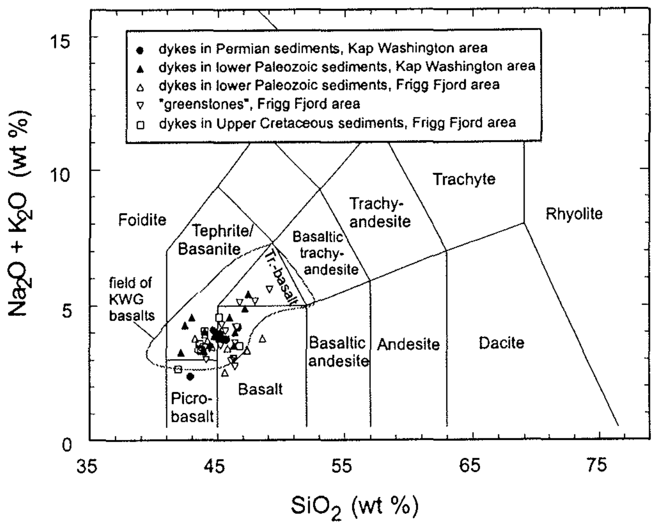

Fig. 2: Dyke rocks in the (Na_2+K_2O vs. SiO_2 classification diagram of LE MAITRE (1989).

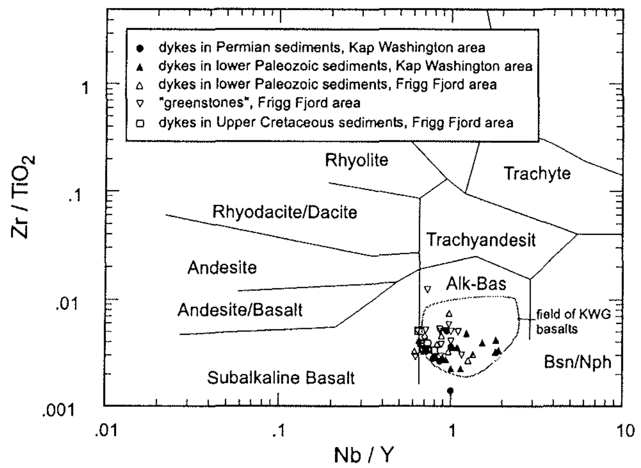

Fig. 3: Dyke rocks in the Zr/TiO_2 vs. Nb/Y classification diagram of Winchester & Floyd (1977).

In geochemical discrimination plots for geotectonic setting, the dykes correspond to intra-plate basalts (Figs. 4 and 5). In the Nb-Zr-Y diagram of Meschede (1986), most of the samples plot in the AII field (Fig. 4); a few samples from dykes in the Ellesmerian basement of the Kap Washington area plot in the AI field. The basalts of the Kap Washington Group are distributed evenly in the AI and AII fields (Estrada et al. in press).

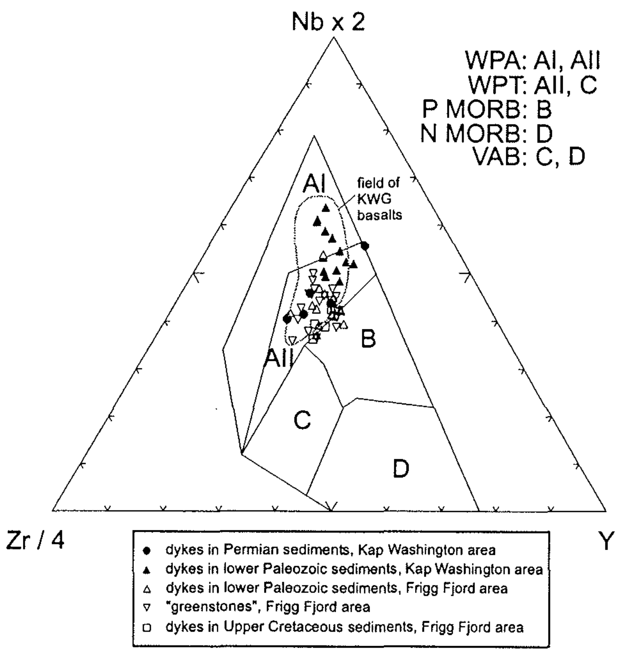

Fig. 4: Dyke rocks in the Nb-Zr-Y diagram for geotectonic setting of Meschede (1986).

CONCLUSIONS

There are no significant petrological or geochemical differences between the dykes which cut Lower Paleozoic to Upper Cretaceous sediments in the Frigg Fjord area and those in the Kap Washington area. Geochemically, according to Soper et al. (1982), all dyke rocks are comparable to intra-plate alkaline

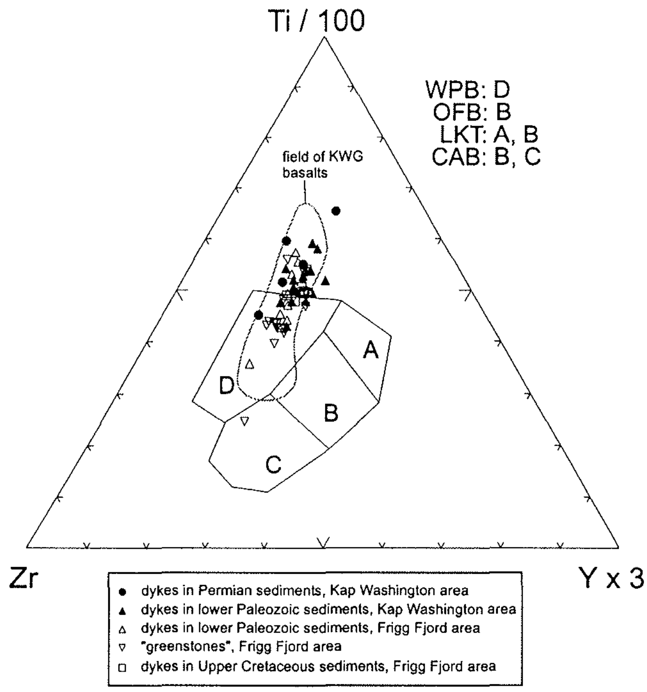

Fig. 5: Dyke rocks in the Ti-Zr-Y diagram for geotectonic setting of Pearce & Cann (1973).

basalts and, in this respect, are similar to the basalts of the Kap Washington Group (Brown et al. 1987, Estrada et al. in press). We can therefore postulate that they originate from a similar magma source and formed roughly coevally in a continental rift zone.

Thus, the age of the dykes is inferred to be close to that of the Kap Washington Group, which is dated biostratigraphically as Upper Cretaceous (Batten et al. 1981) and radiometrically as 64 Ma, i.e. at the Cretaceous-Tertiary boundary (Larsen 1982, Estrada et al. in press), as already discussed by Soper et al. (1982). The youngest sediments in which the dykes occur are Upper Santonian (Frigg Fjord area). This fact and the absence of volcanogenic components in the Santonian sequence (Håkansson et al. 1994, investigations during CASE 2) indicate that the volcanism did not start before Late Santonian time. A palaeomagnetic age of 57 ±10 Ma was determined by Abrahamsen et al. (1997) for NW–SE and E–W trending dykes in central and southern Nansen Land north and south of the Harder Fjord fault zone, west of the present study areas.

The so-called „greenstones of unknown age“ in the western Frigg Fjord segment of the HFFZ are interpreted as relics of E–W trending dykes that were mechanically fragmented and locally tectonically disrupted by the subsequent Eurekan compressive deformation. Mineralogically, these rocks are less strongly altered than the dykes occurring further north in the Lower Paleozoic basement, close to the Kap Cannon thrust zone. The „greenstones“ and other dykes in Lower Paleozoic sediments have similar Nd and Sr isotopic signatures and form a common trend in the ε_{Nd} (t) vs. $(^{87}Sr/^{86}Sr)_t$ diagram (Estrada et al. in press).

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