STRUCTURAL ASPECTS OF KIMBERLITE DYKE AND SHEET INTRUSION IN SOUTH-WEST GREENLAND.

by

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Field relationships of kimberlites have been extensively examined since their first reported occurrence (Andrews & Emeleus, 1971). Three localities, Nigerdlikasik, Midternaes and Pyramidefjeld, were revisited in Summer 1971 and approximately 20 km (along strike) of outcrop remapped.

Field Relationships

(a) Nigerdlikasik. Kimberlite intrusion as a narrow dyke of rather constant thickness and trend took place at an oblique angle to a strong regional fabric in inhomogeneous Archaean gneisses. Throughout a total length of outcrop exceeding 3000 m en - echelon replacement takes place at 700 - 800 m intervals with a consistent dextral offset of 20 - 50 m. Closely spaced parallel jointing is a conspicuous feature of the host rock over a zone commonly 5 - 10 m wide, about ten times the width of the dyke. Selective erosion has developed shallow gullies commonly filled with rubbly pieces of grandioritic gneiss, obscuring the kimberlite which may occupy anywhere between the axial zone and margins and frequently lies along one margin.

(b) Pyramidefjeld. Kimberlite sheets occupy parts of the Precambrian Pyramidefjeld granite complex at various levels between 400 and 900 m, sometimes extending beyond the granite contact into the host Archaean gneisses. Three distinct systems of interconnected sills can be outlined by stratum contours in the north (Vestvoldgrav - Østvoldgrav), north-central (Safirsø - Blokpas) and south-east (Grydesø) areas of granite. Sheets overlooking Vestvoldgrav and Østvoldgrav dip north at 10 - 20 degrees outcropping between 700 and 800 m. Sheets on the south-east side of Safirsø dip gently south-east and outcrop at a lower level along the north-east side of Blokpas, a valley running between the two granites which make up the complex. Around Grydesø at least five different levels with 20 - 50 m intervals are developed with gentle northerly dips which bring the highest level underground at the northern end of the lake. The lowest level extends at least 1 km beyond the granite contact. The granite around most sheets is invariably well jointed parallel to the intrusion margins in the manner of the Nigerdlikasik dyke. The tendency for the sheets to erode into the granite giving rise to small caves and rock shelters has resulted in large collapse structures, especially where the jointing is very closely spaced. Ice action has exaggerated the effect by producing bench features sometimes 20 - 30 m wide. Not all shatter zones and bench features are accompanied by kimberlite and some contain sheets only 10 mm thick. En - echelon relationships are so common that it is rarely able to follow one intrusion more than 100 m before it dies out and some sheets expand and contract rapidly to give the bodies a very laccolithic profile.

(c) Midternaes. Kimberlite sheets generally dip westward rising from sea level at Sioralik glacier to almost 600 m in the high ground to the north-east. The intrusion pass upwards through Archaean gneisses and across an unconformity into a Proterozoic supracrustal succession. The planar foliation in the gneisses and well developed bedding surfaces in the supracrustal rocks have little or no influence on the attitude of the sheets which higher in the succession cut across bedding at very acute angles. The massive basement gneisses and supracrustal rocks where they are tightly folded and indurated develop the characteristic well jointed or shattered aspect familiar in the Pyramidefjeld complex.

Mechanism of intrusion

Kimberlites in all three localities were intruded along zones of pronounced platy jointing. Similar features have also been noted in granite host rock to the Kisiri sills in Tanzania (Williams, 1939) though they have evidently not been readily recognised in association with other kimberlite sills (Hawthorne, 1968). As the zones occur only in association with kimberlites, development of the jointing must have immediately preceeded the kimberlite magma: the sheets themselves are massive and occasionally follow irregular paths through the shattered rocks. Internal calcite-filled fractures developed as the magma consolidated and are a consequence of shrinkage accompanying crystallisation. The volatile rich nature of kimberlites suggests that the magma was accompanied by massive gas emanations which preceeded the magma and were instrumental in leading to the brittle failure of the host rocks. These gases are thought to have passed along those parts of well jointed zones which are barren or almost barren of kimberlite for short distances along strike. Evidence of volatile activity occurs on Midternaes where metasomatism from kimberlitic fluids has completely calcified a siltstone member of the supracrustal succession, for up to 2 m from the contact. The process is confined to a zone beneath a thick gabbro sill indicating that the massive impermeable sheet has acted as a confining cap rock. Along strike where the kimberlite cuts the lower part of the gabbro the latter is anastomized by a network of calcite veins.

Once the way had been opened by brittle failure of the host rocks emplacement of the kimberlite magma took place very rapidly, though not explosively as very few xenoliths of local rock types have been found. Though thermal contact effects are virtually absent there has been small scale mechanical shattering of the granite and gneisses extending only for a few millimetres. Nodules with high-pressure pyrope-garnet are preserved in many places and rounded lower-crustal xenoliths with pyroxene-granulite facies mineralogy have not been recrystallised. Rapid lateral movement of magma carried the dense peridotite xenoliths to most parts of the sheet systems. Xenocryst-bearing kimberlite penetrates the finest channels with some nodules lodged in passages barely wider than the nodule diameters.
When the magma stopped moving, peridotite xenoliths in the sheets sank to the bottom resulting in dense concentrations of nodules

superficially resembling conglomerates. Later pulses of magma followed along or within the first sheets which accumulated up to two or three layers of sedimented xenoliths. Rarely the later kimberlite takes a different path and becomes separated from the earlier sheets by thin screens of host rock. These features together with some size sorting of crystals suggest a very fluid magma with little variation in magma viscosity. There is no evidence of any pipes or other forms of blowout to suggest that the kimberlites ever reached the open surface.

Structural control of dyke and sill intrusion

The overall pattern of kimberlite intrusion reveals a complete disregard for preferential planes of weakness in gneisses and supra-crustal rocks, splendidly displayed on Midternaes. Structural control is ascribed not to pre-existing inhomogeneties in the host rocks but to the prevailing external stress field. Following Anderson (1951) sills are intruded under conditions of horizontal compression and dykes under horizontal tension. Theoretically the alternating stress conditions necessary to explain both kimberlite dykes and sills can be brought about by major crustal flexures (Sanford, 1959) such that sills intrusion would occur within regions of downward displacement and dyke intrusion within regions of elevation. These conditions were probably realised at the time of kimberlite emplacement, at some time during the early Mesozoic (Andrews & Emeleus, 1971), since the early stages of continental rifting between Greenland and Canada were then taking place. Graben formation in northern West Greenland during the Cretaceous is documented by Rozenkrantz and Pulvertaft (1969) and probably followed a period of updoming similar to that over the East African rift system. Conditions would be created for dyke intrusion on the margins. A coast - parallel Jurassic dolerite dyke swarm flanking the coastal strip of S.W. Greenland (Watt, 1969) supports the early development of axial doming: fringe members of this swarm straddle the Nigerdlikasik dyke. Dolerite dykes do not extend as far inland as Pyramidefjeld and Midternaes, areas marginal to the Inland Ice, and kimberlite sill intrusion took place under horizontal compression.

References

Anderson, E.M., 1951 The dynamics of faulting. 2nd ed. Oliver & Boyd, Edinb.

Andrews, J.R. & Emeleus, C.H. 1971 Rept Grønlands geol.Unders., 31.

Hawthorne, J.B. 1968 Trans.geol.Soc. S.Africa, LXXI, 291-311.

Rozenkrantz, A. & Pulvertaft, T.C.R. 1969 Mem.Amer.Assoc.Petroleum Geologists, 12, 883-898.

Sanford, A.R. 1959 Bull. geol. Soc. Amer., 70, 19-.

Watt, W.S., 1969 Can.J.Earth. Sci., 6, 1320-1321.

Williams, G.J., 1939 The kimberlite province and associated diamond deposits of Tanganyika Territory. Dpt. of Land and Mines, Geol. div., Tanganyika Govt. Printer, Dar-es-Salaam, 41p.