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The Importance and Potential of Mafic Dyke Swarms in Studies of Geodynamic Processes

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Discussions

The Importance and Potential of Mafic Dyke Swarms in Studies of Geodynamic Processes

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Halls' excellent review article, The Importance and Potential of Mafic Dyke Swarms in Studies of Geodynamic Processes (Halls, 1982, v. 9, p. 145-154), should not be allowed to pass without comment. It is well-written, timely and provocative, and its potential is exciting. It is a great contribution, and I hope it will be followed by intensive studies.

Seventy-Five years of Progress
Halls' article can be regarded as the culmination of 75 years of mapping and research on the Canadian Shield. The olivine diabase dykes in the Sudbury area were noted by Coleman (1905), who described them as numerous and very fresh. Several were mapped by Walker, and Barlow traced the dyke at Murray Mine 6 miles to Ramsay Lake. In 1929, Burrows and Rickaby indicated at least 5 sub-parallel dykes in the Sudbury Basin.

In 1930, I made a photogeological map of the Sudbury Basin, as a base for field mapping, and Collins' maps were published posthumously (GSC Maps: 291A, 292A, 871A, 872A). The olivine diabase dykes were traced across the entire area, and a dipmeter was used to connect outcrops across muskeg and drift-covered areas – modern geophysical methods were not yet available. (For some unexplained reason, Map 871A omits the main Sudbury-Chelmsford dyke shown by Burrows and Rickaby, 1929, Map 38g.) The most striking features noted at the time were the almost invariable strike of 120°, the parallelism, attitude, uniform composition and grain size. By 1935 (Collins, 1935) some 40 dykes had been mapped in or close to the Sudbury Basin. These are remarkable for their abundance and sub-parallel arrangement and, except for rotation of the craton, are unaffected by later movements. The dyke swarm extends over an area of 400 km in diameter; in the western part they strike at 125°, and swing gradually to 115° in the east part (Collins, 1935, Fig. 3), varying from 30 cm to 120 m in width. Generally, the dykes are not more than 16 km long and there is no displacement of the walls: they are just simple tension fissures. In the Sudbury area the dykes exhibit a left-hand *en echelon* offset of as much as 400 m. Similar dyke swarms have been recognized in the Cobalt area, and are abundant in the Michipicoten area. Previously, there was no way in which to visualize how they fitted into the regional picture, as few areas of Canada had yet been mapped in detail. Now, a clear picture is emerging, and Halls' article contributes substantially to this clarification.

In the 1930s, we could only speculate as to the possible source of the olivine diabase magma. Age dating by the Helium method also was attempted (Keevil, 1938). Intrusion must have been sudden – flash-injection – and the magma source must have underlain the entire Sudbury area. If we look at Fig. 4 (Halls, 1982, p. 150), we can see that the magma source must underlie the entire Shield area – the whole Precambrian continent of 1.2 Ga.

In hindsight, Fahrig's two papers on the diabase dykes of the Canadian Shield (Fahrig, *et al.*, 1963, 1965) were major contributions. Although both were initial reports, they demonstrated that large areas of the Shield are intruded by swarms of sub-parallel basaltic dykes. Age dating and paleomagnetic measurements on six of these indicated that the Mackenzie and Sudbury sets were probably one event which was thought to be of short duration, and together cover come 2 million km^2. In subsequent papers, the picture became much clearer. Nearly all the dyke swarms were shown on the Tectonic Map of Canada (GSC Map 1251A, 1969), but their real significance was not appreciated, and is only now becoming apparent.

Magma Source?
I am puzzled by the frequent references to magma chamber, feeder magma chambers, elongated magma chamber, teardrop shape, depth and size of magma sources, intrusion depth, density contrast between magma and host rock, sub-horizontal magma flow, etc. Surely the source of the magma only can be from below the brittle crust, possibly from below the sima or from the Upper Mantle. The reservoir would be a deep horizon where the temperature of the rock is above the melting point and prevented from melting by the geostatic pressure. When a surface fracture penetrated to the base of the brittle crust, it would suddenly reduce the magma pressure to near surface conditions and instantaneous flash-intrusion of a superheated liquid would result as the superheated rock became liquid. The magma source must have been an interface, or horizon, at or near the base of the brittle continental crust, and global in extent. It is interesting to note that where the diabase dykes cut the massive sulfide ore at the Creighton and Murray mines, they have a chilled glassy margin, showing that the magma was entirely liquid at the time of intrusion.

Origin of the Fracture Pattern?
These must have been tension joints that opened up. They were influenced by a regional stress field of global proportions. Metastasy, or the shift of the entire brittle crust on the interior of the earth (Gussow, 1963), is still the best explanation for such a fracture pattern, which ruptured the brittle continental crust by a shift in latitude of the earth's crust on the interior; tension

was caused by stretching of the crust as it was rotated out of a shorter polar circumference toward a greater equatorial circumference. Tension fractures would be initiated and propagated with great speed, accompanied by simultaneous flash-intrusion. This also would explain the preferred north-south orientation of Precambrian dyke swarms at the time of intrusion, and their polar convergence. Morris (1978) recognized this preferred orientation of intrusion of Precambrian dyke swarms, but was unable to suggest a mechanism.

Selected References

Burrows, A.G., and H.C. Rickaby, 1929, Sudbury Basin area: Ontario Bureau of Mines, Annual Report., v. 38, pt. 3, (Map 38g).
Coleman, A.P., 1905, Sudbury nickel field: Ontario Bureau of Mines, Annual Report, 1904, v. XIV, pt. 3.
Collins, W.H., 1938, Espanola Sheet, Geological Survey of Canada, Map 291A, 1in:1mi.
Collins, W.H., 1938, Copper Cliff, Geological Survey of Canada, Map 292A, 1in:1mi.
Collins, W.H., 1946, Chelmsford, Geological Survey of Canada, Map 871A, 1in:1mi.
Collins, W.H., 1946, Falconbridge, Geological Survey of Canada, Map 872A, 1in:1mi.
Collins, W.H., 1935, and E.D. Kindle, 1935, The life history of the Sudbury nickel irruptive II, Intrusion and deformation: Royal Society of Canada, Transactions, series 3, v. 29, pt. 4, p. 27-47.
Fahrig, W.F., and R.K. Wanless, 1963, Age and significance of diabase dyke swarms of the Canadian Shield: Nature, v. 200, no. 4910, p. 934-937.
Fahrig, W.F., E.H. Gaucher, and A. Larochelle, 1965, Paleomagnetism of diabase dykes of the Canadian Shield: Canadian Journal of Earth Sciences, v. 2, pt. 4, p. 278-298.
Geological Survey of Canada, 1969, Tectonic Map of Canada, Map 1251A, 1:5,000,000.
Gussow, W.C., 1963, Metastasy, in Polar wandering and continental drift: Society of Economic Paleontologists and Mineralogists, Special Publication 10, p. 146-169.
Halls, H.C., 1982, The importance and potential of mafic dyke swarms in studies of geodynamic processes: Geoscience Canada, v. 9, pt. 3, p. 145-154.
Keevil, N.B., 1938, The application of the helium method to granites: Royal Society of Canada, Transactions, series 3, v. 32, sec. 4, p. 123-150.
Morris, W.A., and E.I. Tanczyk, 1978, A preferred orientation of intrusion of Precambrian dykes: Nature, v. 275, p. 120-121.
Thomson, J.E., 1956, Geology of the Sudbury Basin: Ontario Department of Mines, 65th Annual Report, p. 1-56. (Map No. 1956-1.)

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