GEOCHEMISTRY AND REGIONAL SIGNIFICANCE OF THE EARLY CRETACEOUS BASALT-FELSIC IGNEOUS ROCK ASSOCIATIONS ON THE GRAND BANKS, EASTERN CANADA

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ABSTRACT

CRETACEOUS mafic rocks occur in several wells on the Grand Banks of Newfoundland, near the southwest Grand Banks Jurassic transform margin and along the trend of the Collector magnetic anomaly. In the Brant and Mallard wells felsic volcanic, subvolcanic and pyroclastic rocks are several hundreds of metres thick. Seismic reflection profiles show that the igneous rocks are locally bounded by rejuvenated faulted margins of early rift basins beneath the mid - Cretaceous, post-rift unconformity. Several K/Ar dates on the Mallard rocks range from 127 to 133 Ma; the only date at Brant is 136 Ma. The concentration of Cretaceous igneous rocks in the Fogo Seamounts along the late Jurassic transform margin suggests that magma was generated along the reactivated transform margin and that major faults in continental crust acted as magma conduits.

Whole rock geochemistry and isotopic composition, together with mineral chemistry, show that the felsic rocks resemble alkaline A-type granites. Those from Mallard have some crustal contamination; those from Brant, which is located closer to the continental margin edge have almost pristine mantle isotopic characteristics. Felsic rock geochemistry is consistent with partial melting of relatively dry metagabbro.

There is no geochemical evidence for mantle plume activity beneath the southern Grand Banks. Rather, the volcanism appears to be a consequence of partial melting in the oceanic plate along the transform margin as a result of tectonic adjustments of crustal blocks. Both depression of lithospheric mantle, or local extension and pull-apart along the fault would result in magma production. In either case, partial melting of an old, deeper oceanic crust (metagabbro) would produce primitive felsic magma.

INTRODUCTION

Cretaceous volcanic rocks occur on the southwest Grand Banks and northeastern Scotian shelf. Felsic volcanics occur only in the Brant and Mallard wells.

Hypotheses for the origin of these igneous rocks are:
1. Extensional decompression of underlying mantle during Cretaceous basin formation.
2. Passage of one or more of the Atlantic hot-spots beneath the Grand Banks.
3. Depression of continental crustal blocks as result of major continental plates reorganization accompanied by lateral migration of the magma.

These hypotheses are tested by examining:
A. Relationship of the volcanics to rift basins
B. Geochemistry of the volcanics
C. Isotopic characteristics of the volcanics

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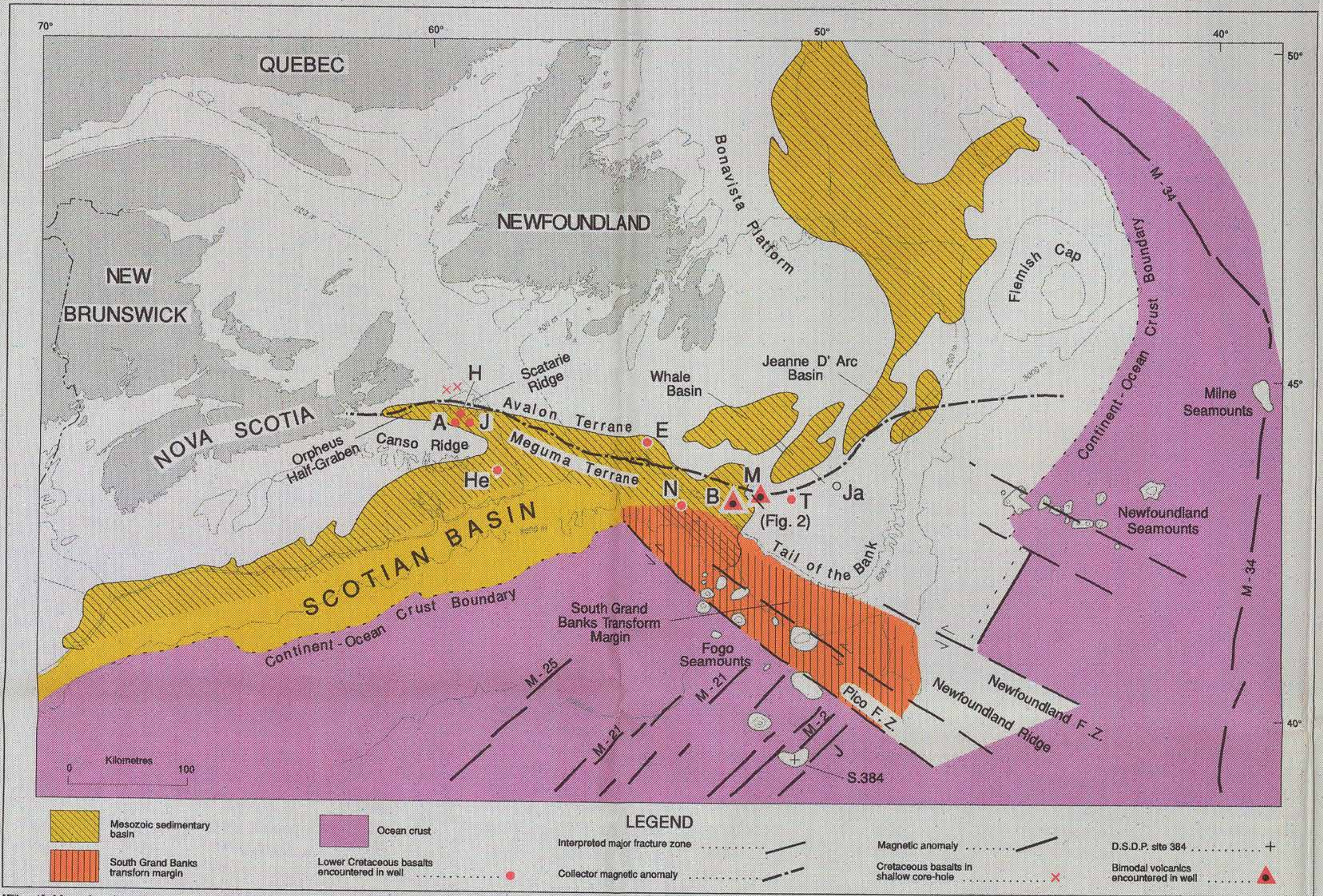
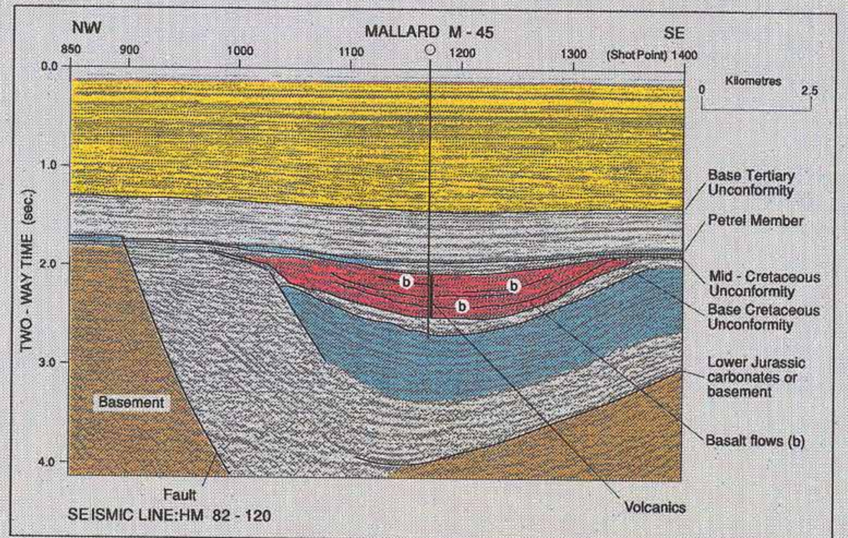
A. RELATIONSHIP OF THE VOLCANICS TO RIFT BASINS



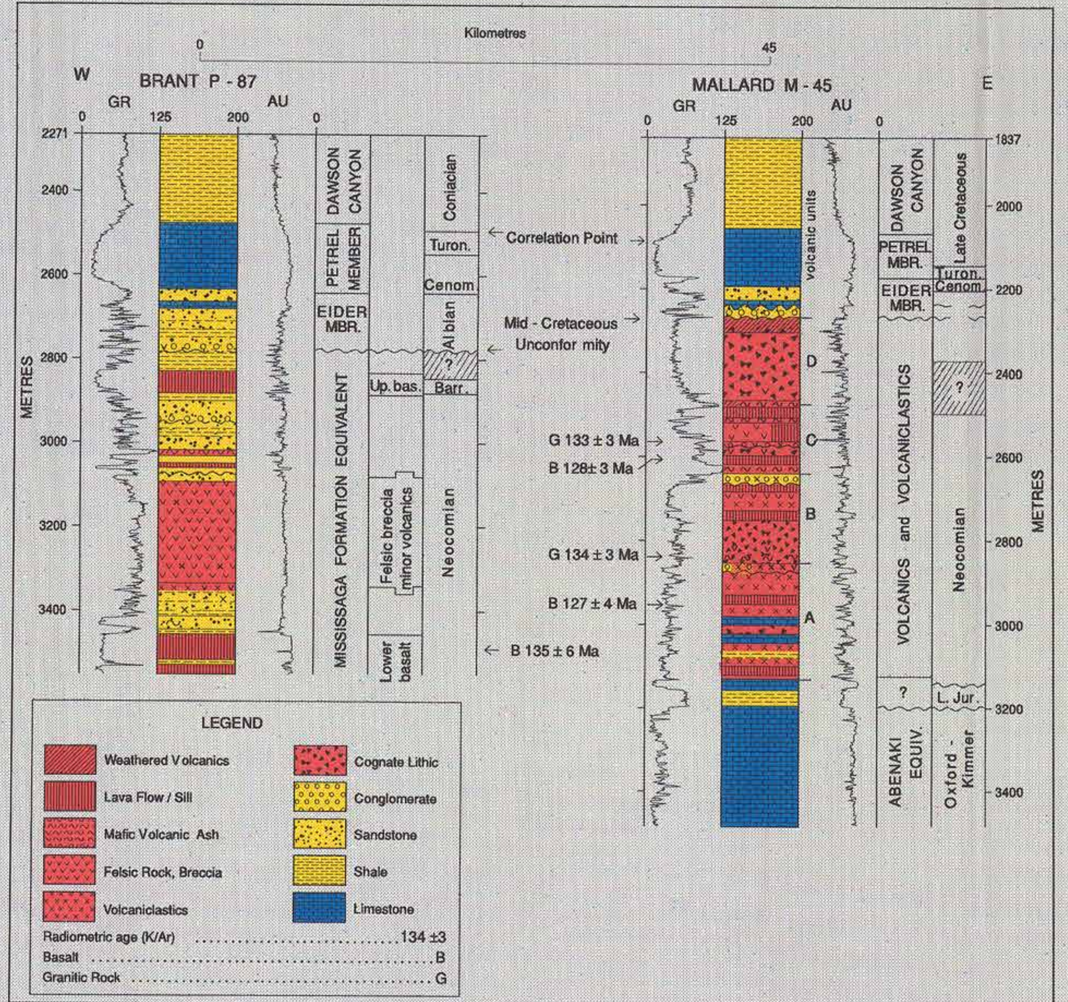
[Fig. 1] Map showing the localities of felsic igneous rocks offshore on the Grand Banks in relationship to major structural, geological and geophysical features.

CONTINENTAL - OCEAN crust boundary has been modified after MacLean and Wade (1991) and Grant et al (1988). Magnetic lineations are adopted from Klitgord et al (1986). Location of Fogo Seamounts and fracture zones off southern Grand Banks are after Jansa (in prep.). OEOW which encountered Cretaceous igneous rocks are: A-Argo F-38, B-Brant P-87, E-Emerillon C-56, H-Hercules G-15, He-Hesper P-52, J-Jason C-20, M-Mallard M-45, N-Narwhal F-99, T-Twillick G-49, S.384-ODP Site 384. Other wells: Ja-Jaeger A-49.



[Fig. 2] Seismic reflection profile from the Mallard M-45 well showing volcanic rocks and intercalated basalt flows filling a syncline. Note that the volcanic sequence is enclosed between two early Cretaceous unconformities.

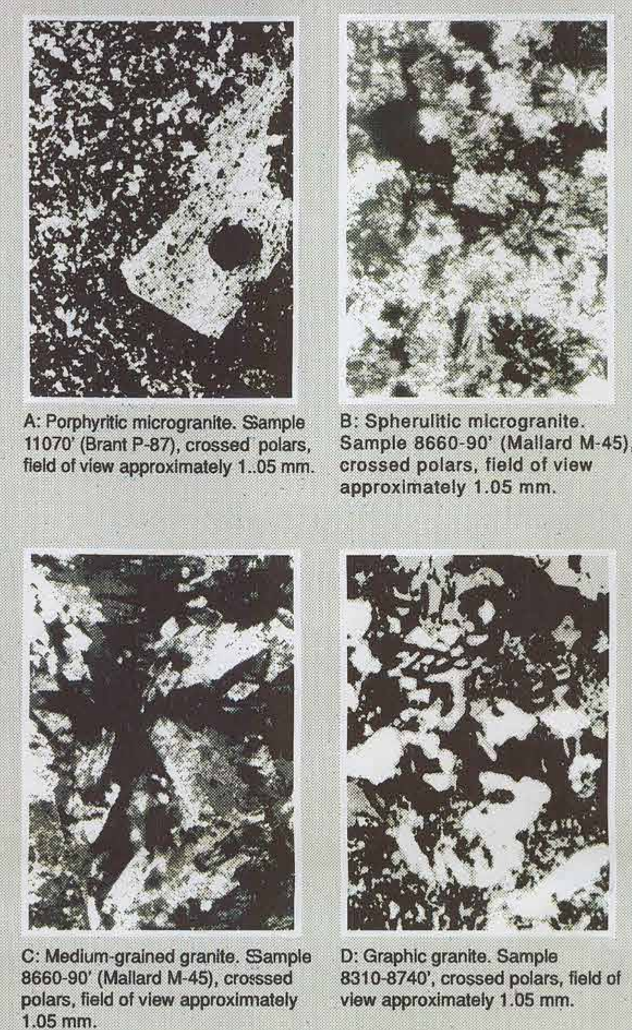
IGNEOUS rocks are associated with the small rift basins on the southwest Grand Banks. None are found in the larger Jeanne d'Arc rift basin. It therefore seems unlikely that the volcanic rocks are a direct result of basin extension and Cretaceous rifting.



[Fig. 3] Lithologic profiles of the Brant and Mallard wells, showing stratigraphic position of igneous rocks. Gamma ray and sonic logs are also shown.

B. GEOCHEMISTRY OF VOLCANICS

[Fig. 4] Microphotographs of representative felsic rocks:

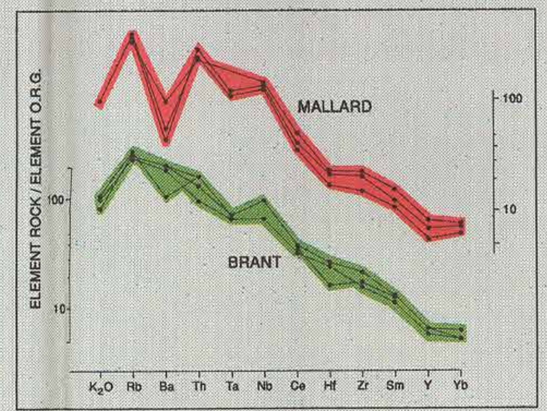


A: Porphyritic microgranite. Sample 11070' (Brant P-87), crossed polars, field of view approximately 1.05 mm.

B: Spherulitic microgranite. Sample 8660-90' (Mallard M-45), crossed polars, field of view approximately 1.05 mm.

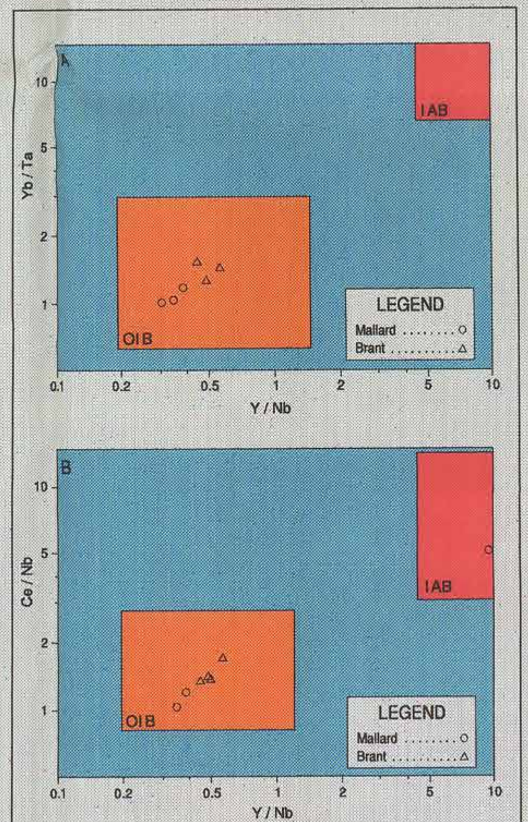
C: Medium-grained granite. Sample 8660-90' (Mallard M-45), crossed polars, field of view approximately 1.05 mm.

D: Graphic granite. Sample 8310-8740', crossed polars, field of view approximately 1.05 mm.



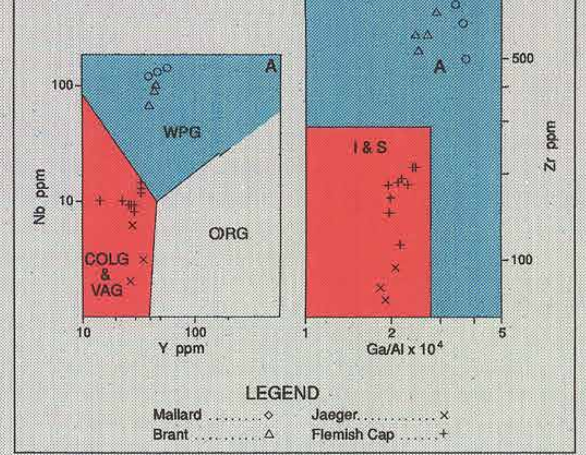
[Fig. 6] Trace element abundances of felsic rocks from Brant and Mallard showing within-plate character compared with Ocean ridge granite (ORG) (Pearce and others, 1984).

The Mallard well contains felsic rocks with aegirine and arfvedsonite, indicating the alkaline nature of the parent magma.



[Fig. 7] Yb/Ta vs. Y/Nb and Ce/Nb vs. Y/Nb plots showing OIB-type character of the A-type granites.

The fields for OIB (oceanic-island basalt) and IAB (island-arc basalt) are after Eby (1992). The OIB type of granite is associated with intraplate rifting, usually with abundant coeval mafic rocks, or with plume or hotspot activity.

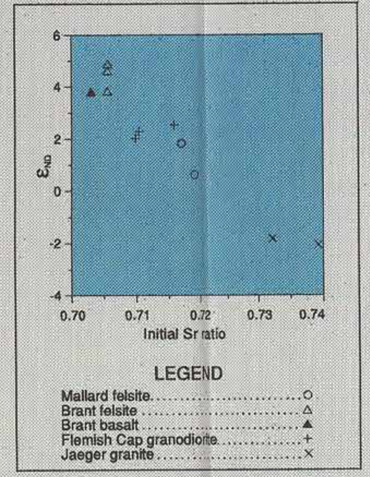


[Fig. 5a] Y vs. Nb tectonic discriminant diagram showing within-plate character (Pearce and others, 1984); WPG-within-plate granites; COLG-collisional granites; VAG-volcanic-arc granites; ORG-ocean-ridge granites.

[Fig. 5b] Ga/Al vs. Zr discriminant diagram showing A-type granite character (Whalen and others, 1987). I & S - I-type and S-type granites.

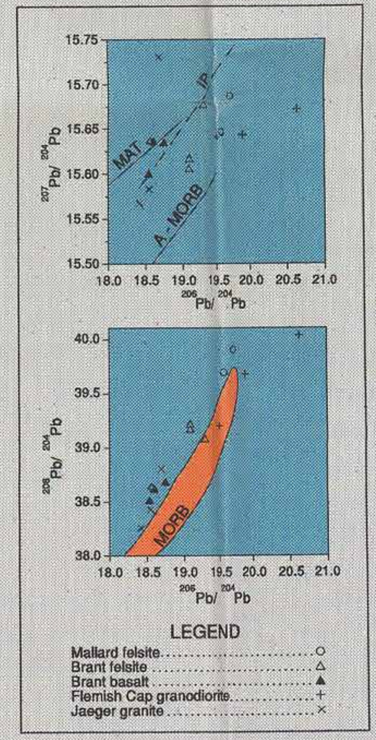
GEOCHEMICAL discrimination diagrams show that the felsic rocks have the characteristics of within-plate A-type granites.

C. ISOTOPIC CHARACTERISTICS OF VOLCANICS



[Fig. 8] ε_{Nd} vs. initial 87Sr/86Sr ratio

Both ε_{Nd} values and T_{DM} ages of the Brant felsites are similar to those from coeval basalts (498-489Ma). The slight variations in values are within the range expected from crustal contamination.



[Fig. 9] Pb isotope variation and comparison with other rocks

MAT = Mesozoic Appalachian tholeiites (after Pegram, 1990); A-MORB = Atlantic MORB after Dupré and Allègre (1980); IP = trend of Cretaceous intraplate mafic volcanics (from Lambert and others, in prep.); MORB field from Sun (1980).

TWO main processes may have produced the voluminous felsic magma:
(1) anatexis or assimilation of large amounts of continental crust.
(2) partial melting of underplated metagabbro at the base of the crust.

BRANT mafic and felsic rocks have similar Nd and Sr isotopes to the mantle array, suggesting little crustal contribution. Pb isotopes indicate minor crustal contamination.

Mallard Nd and Sr isotopes indicate a substantial crustal contribution.

MODEL FOR THE FORMATION OF THE CRETACEOUS VOLCANIC ROCKS OF THE SOUTHWEST GRAND BANKS

Neither the isotopes nor the geochemistry indicate that volcanism is related to a hotspot or mantle plume.

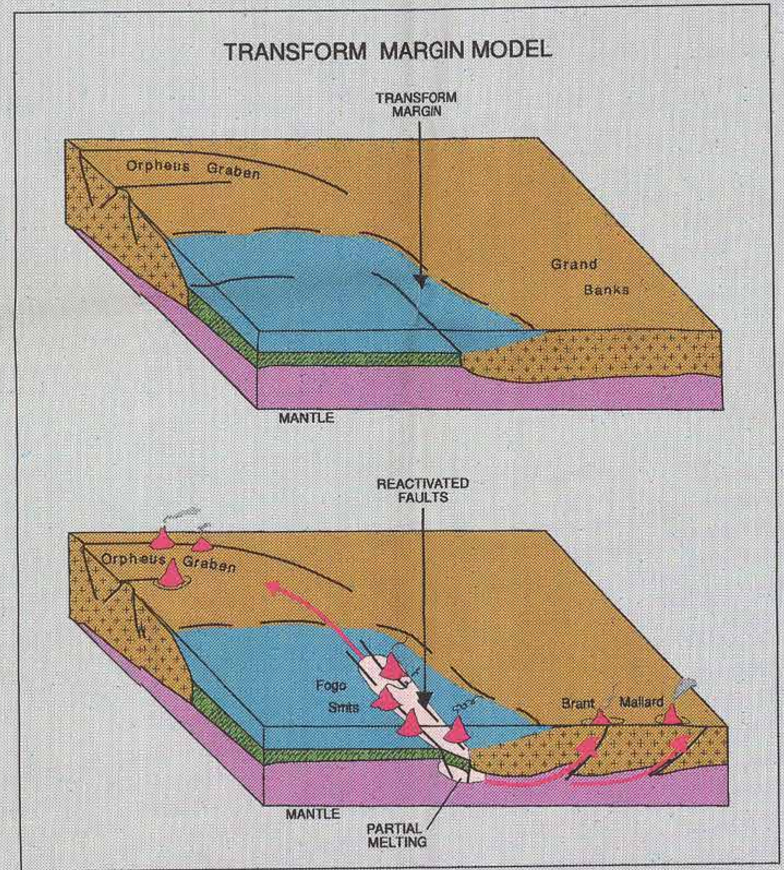
MAFIC rocks derived from hot-spots or plumes show enrichment in LREE, LILE, and some radiogenic Pb isotopes. The Cretaceous mafic rocks of the Grand Banks do not show such features: rather, they have almost identical isotopic composition to the Hettangian basalts from the Cormorant well on the northeastern part of the Grand Banks. Plume-related Cretaceous basalts from the New England Seamounts are substantially enriched in LREE, LILE and radiogenic Pb compared with the Brant basalts.

Partial melting of an older oceanic plate along the Grand Banks transform margin is a probable source of magma.

PARTIAL melting would result from tectonic adjustments along the transform margin, either as a result of extensional decompression, or depression of lithospheric upper mantle. In either case, partial melting of mantle would produce basaltic magma. Melting of lower oceanic crust (layer III, metagabbro) would produce primitive felsic magma.

Major crust-cutting faults provide pathways for magma.

DEEP seismic profiles of the southern Grand Banks show that major faults cut the entire crust and offset the Moho (Keen and others, 1987). The concentration of Cretaceous volcanism along the Collector Anomaly, the Orpheus half-graben, and the strike-slip continental margin of the southwest Grand Banks indicate that major faults had an important role in magmatic activity.



[Fig. 10] Schematic block diagram showing sites of partial melting and magma migration to produce the Cretaceous volcanism offshore southeastern Canada

CONCLUSIONS:

1. Thick felsic volcanic and subvolcanic rocks associated with alkalic basalts occur in mid - Cretaceous rift basins and were encountered in the Brant and Mallard wells on the southern Grand Banks.

2. The greatest volume of Cretaceous volcanic products is concentrated along the southwest Grand Banks margin (Fogo Seamounts), which was an active middle to late Jurassic continent-continent sheared zone. Lesser volcanism occurs along the landward continuation of this sheared margin trend into the Orpehus half graben, and along the Collector Anomaly, which represents a Paleozoic sheared margin suture. These relationships suggest that magma was generated along zones of crustal weakness, as represented by the reactivated transform faults of the transcurrent margin, with the major faults in continental crust acting as magma conduits.

3. There is no geochemical evidence for hot spot, or plume activity beneath the Grand Banks.

4. Magma generation along the transform margin was triggered by changes in the intraplate stress field resulting from plate reorganisation as the Iberia and Grand Banks continental plates separated; either through compression and isothermal depression of parts of the oceanic lithosphere; or through extensional pull-apart and adiabatic decompression.

5. The felsic rocks are the product of partial melting of relatively dry metagabbro at the base of older Jurassic oceanic crust, where this abuts the continental crust. Mallard, located farther from the continent-oceanic crust boundary, shows more crustal contamination of the magma than Brant, where isotopic and geochemical characteristics show little difference from mantle-derived alkalic basalts.