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ARCHEAN MEGACRYSTIC PLAGIOCLASE UNITS AND THE TECTONIC SETTING OF GREENSTONES

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Large (up to 20 cm), equidimensional, commonly euhedral, plagioclase megacrysts of highly calcic composition (An_{80-90}) occur commonly in all Archean cratons in one or more of three distinct associations:
1) as cumulate crystal segregations of anorthosite or as megacrysts in basaltic dikes, sills, and flows in greenstone belts that vary in metamorphic grade from greenschist to granulite. Throughout 100's of thousands of square kilometers of northwestern Ontario and Manitoba the plagioclase megacrysts occur in pillowed and massive flows, sills, dikes, large inclusions in dikes, and intrusive anorthositic complexes (Fig. 1) with areas of up to a few 100 km^2 and spanning a period of at least 100 m.y. in the 2.7 to 2.8 b.y. time frame,
2) as basaltic dike swarms in stable cratonic areas forming parallel to subparallel patterns over hundreds of thousands of square kilometers intruding both granitic gneisses and supracrustal belts including greenstones. These swarms include the Ameralik-Saglek system at 3.1 to 3.4 b.y. (Fig. 2) [1], the Matachewan system at 2.5 to 2.6 b.y. [2], and the Beartooth-Bighorn system at 2.2 to 2.3 b.y. [3], and
3) as anorthositic complexes associated with marbles and quartzites (Sittampundi, India and Messina, South Africa) in granulite grade terrains.

Initial attempts to correlate tectonic settings of similar modern cryst-bearing units with their Archean counterparts were only partially successful. Plagioclase phenocrysts of An_{80-90} occur in basaltic volcanic flows in oceanic crust at spreading ridges, hotspots, aseismic ridges, and fracture zones [4]. These recent occurrences, however, normally involve only small phenocrysts up to a few millimeters in size and usually more lathy than equidimensional in shape [5]. In contrast to these normal occurrences, volcanic flows over the Galapagos hotspot display more equidimensional crysts up to 3 cm across [4]. Although these oceanic environments might be satisfactory tectonic analogs for many greenstone occurrences, they certainly are not satisfactory for the extensive dike swarms in stable cratonic masses. Thus we turn for clues to a more detailed understanding of the petrogenesis of the crysts and related melts.

The crysts are quite homogeneous, varying by little more than one to two An units over several centimeters thereby suggesting nearly isothermal crystallization at nearly constant melt composition over the time required to grow crystals commonly 6 to 8 cm across and up to 20 cm across and accumulate them in large masses. Thin, more sodic rims on the order of 100 to 200 μm wide are common on large crysts when the groundmass plagioclase laths are more sodic than the large crysts. The rims normally approach the composition of the plagioclase in the groundmass (Table 1).

The nature of the parent melts, or melts in equilibrium with the large crysts, has been an open question because: 1) the anorthositic complexes are clearly cumulates with bulk compositions too rich in Al_2O_3 and CaO to represent melts [6], and 2) the disparity in composition between plagioclase crysts and plagioclase of the matrix suggests a lack of equilibrium between crysts and the melt represented by their matrix.

Initial attempts to determine melt compositions by use of REE concentrations in megacrysts in conjunction with distribution coefficients for plagioclase and basaltic melts were fraught with problems resulting from modification of plagioclase REE concentrations by alteration, recrystallization, and tiny inclusions. By utilizing several splits from each cryst in several samples from the BVL anorthosite, mixing lines were determined and the least modified REE concentrations were calculated for pristine plagioclases [7]. These values in conjunction with the most recent distribution coefficients indicate melts with nearly flat REE patterns at 10X to 20X chondrites with perhaps a slight depletion in the light REE's. The calculated patterns compare well with several cryst-bearing basalts in greenstone belts (Fig. 3) as well as with the non-cryst-bearing basalts. These patterns are those of the least enriched tholeiitic basalts which are very common in greenstone belts. Comparison of these basalts with those in the cratonic dike swarms shows many similarities (Fig. 3, Table 2) but the initial data suggests that the cratonic dikes are slightly enriched in SiO_2, K_2O, and light REE. It is tempting to attribute these differences to contamination of the melts as they rise through continental crust but the melts of the Galapagos when compared with MORB show some of the same enrichments (Table 2) which in this case cannot be attributed to continental contaminants. Further work on the pristine REE contents of plagioclase megacrysts is underway and should help determine whether megacrysts in enriched melts formed from the more enriched or less enriched tholeiitic melts, or both.

At present the petrogenetic data require, at a minimum, isothermal crystallization of plagioclase megacrysts from tholeiitic melts (the least enriched ones in greenstone belts) followed by segregation of the plagioclase crystals which then become entrained in rising melts to form intrusions or volcanic flows. Furthermore, the occurrences seem to require large volumes of melt at similar temperatures for long periods of time over huge areas having both oceanic and cratonic associations. Continual generation of similar melt and continuous addition of the melt to extensive networks of crystallizing chambers is also strongly implied. The major remaining questions with significant implications for the setting and evolution of greenstone belts are: 1) Does the cryst-producing melt have the same composition and crystallize under the same conditions beneath greenstone belts, stable cratons, and current oceanic crust? 2) Where do the plagioclase crysts form and accumulate; in low or high pressure environments? 3) Is there a systematic change in the time of megacryst emplacement across large areas such as might be produced by plates overriding zones of melt production or other such time-dependent mechanisms?

Refs: [1] McGregor V. R. et al. (1985) Workshop: The Worlds Oldest Rocks, Lunar and Planetary Inst., Houston. [2] Ernst R. E. (1982) Ont. Geol. Surv. Misc. Pap. 106, p. 53-56. [3] Miller J. D. (1980-81) Wyo. Geol. Assoc. Earth Sci. Bull., v. 13-14, p. 187-215. [4] Cullen A. et al. (1985) preprint from Center for Volc. Univ. Oreg. [5] Blanchard D. P. et al. (1976) Jour. Geophys. Res., 81, p. 4231-4246 and Donaldson C. (1977) EPSL, 37, p. 81-89. [6] Phinney W. C. (1982) LPI Tech. Rpt. 82-01, Lunar and Planetary Inst., Houston, p. 121-124. [7] Morrison D. A. et al. (1985) Lunar and Planet. Sci. Conf. XVI, Lunar and Planetary Inst., Houston, p. 589-590.

Table 1

Matachewan Dikes: Plag. Compositions

LOCATION	CRYSTS			MATRIX LATHS	
	main cryst	inner rim	outer rim	core	rim
Sta 8	An79-81	An56	An42-49	An61-64	An47
9-11	80-82	66-69	54	65-69	54
10	75-78	61-62	54	58-61	45-50
16	81-84		62-67	68-70	52-53
16	82-84		64-65	64-66	46-53
16	83-85		72-76	71-72	66-69
18	Too Altered			50-54	33
34	81-83			No laths	
35	81-83		78-80	61-63	51-54

Table 2. Matrices of Cryst-Bearing Tholeiites

	RECENT		ARCHEAN	
	MORB Leg 37	Pinta Galapagos	BRNIB Bird River Greenstone	KD4-6 Cratonic Dike
SiO_2	48.36 %	48.60	48.85	50.09
TiO_2	0.89	2.10	0.96	0.94
Al_2O_3	16.85	16.68	15.00	14.67
Fe_2O_3	3.39	6.52	2.14	2.37
FeO	5.41	3.95	10.14	9.74
MnO	0.17	0.17	0.22	0.19
MgO	7.21	7.23	6.50	6.43
CaO	12.53	12.15	12.07	10.54
Na_2O	2.15	2.80	1.85	2.32
K_2O	0.19	.43	0.29	0.61
P_2O_5	0.08	.31	0.09	0.10
H_2O	2.35	.47	1.76	1.93
La	4.41 ppm	13.00	4.04	9.64
Ce	10.5	36.20	10.12	19.6
Sm	2.11	5.49	2.42	2.96
Eu	0.80	2.02	.895	0.95
Yb	2.19	3.40	2.41	2.414
Lu	.38	.40	.377	0.408

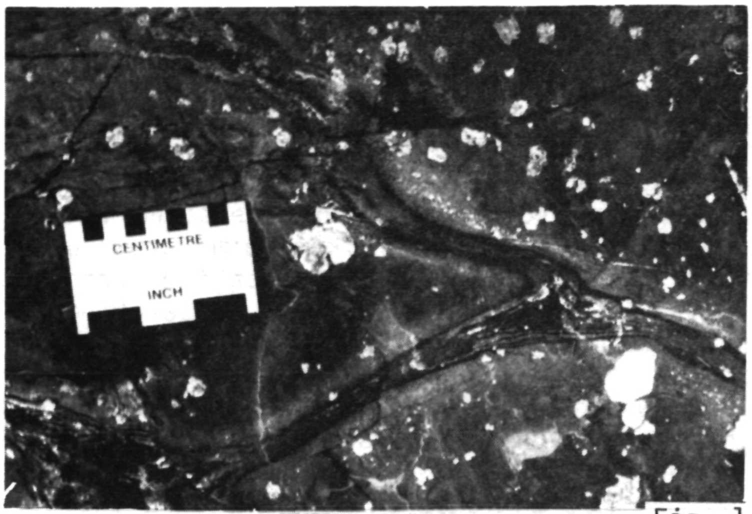
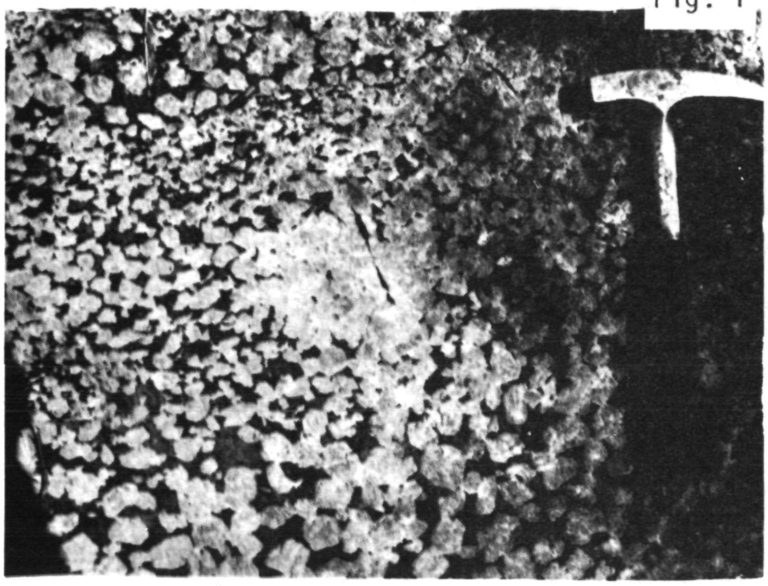


Fig. 1



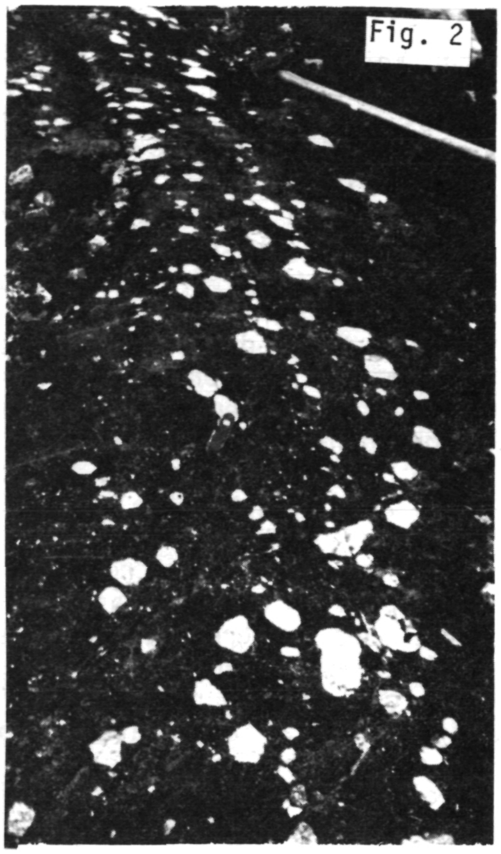


Fig. 2

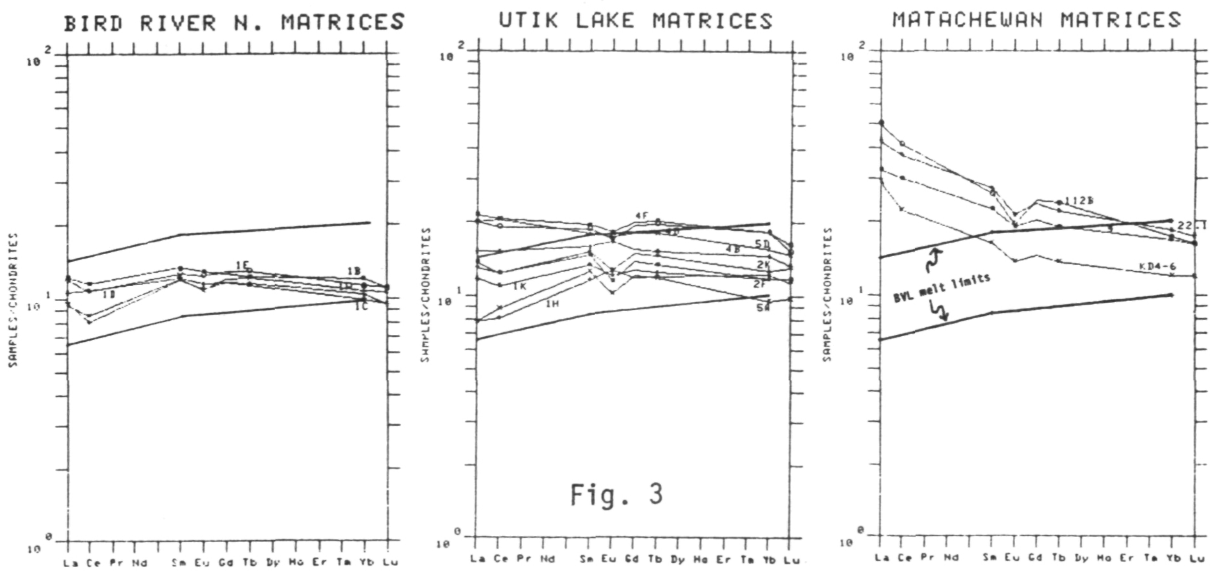


Fig. 3