

Morphology of zircons in massive and incipient charnockites of southern Kerala: Their bearing on the origin

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Morphological characteristics of zircons in massive and incipient charnockites show contrasting features between the two types. Significantly greater length/breadth ratio in massive charnockite suggests crystallization in igneous environment, whereas zircons of incipient charnockites point to extended transport, eventual rounding and deposition in sedimentary environment. Further, morphological data agree with the petrological and geochemical observation that the incipient charnockites are probably the highgrade (granulite facies) reaction products of metasediments (argillaceous and arenaceous) whereas massive charnockites developed from igneous protoliths.

ZIRCON is an accessory mineral of great interest in many rocks. The relative abundance, colour, elongation ratio, degree of rounding of zircons can give positive expression as to the nature of origin of the host rock. In the past, several attempts have been made to resolve some controversial petrogenetic problems of distinguishing igneous rock types, origin of granite, metasomatized rocks, different igneous intrusions in an igneous complex, ortho/para nature of gneisses¹⁻⁵ using the statistical parameters of zircons. Zircon study has been found especially significant in the study of granite.

We have attempted here the morphological study of zircons to address the mode of origin of two types of incipient and massive charnockites. The incipient charnockite is seen as foliation-blurring discordant coarse-grained patches and the massive charnockite occurs as, occasionally banded, large units in southern Kerala. Our interpretation of statistical data is based on the knowledge of field relationships and the observation of several workers⁶⁻⁸ that zircons retain a large extent of their premetamorphic characteristics through higher grade of metamorphism and can survive crustal melting events and remain unrecrystallized even under granulite facies conditions.

Southern Kerala is essentially a granulite-facies terrain. A major shear zone called the Achenkovil shear zone separates the high-grade terrain into a northern region dominated by garnet- and graphite-free massive charnockites, from the southern region dominated by metasedimentaries. The metasedimentary unit, also known as Kerala khondalite belt (KKB) consists of graphitic garnet-sillimanite-biotite-cordierite gneiss with less abundant calc-silicate and quartzites. Widespread

occurrences of incipient charnockites are noted within the supracrustal assemblages of the KKB. Rb-Sr and U-Pb dating of khondalite group suggest the age of khondalite to be 1900–2200 my (ref. 9–11). It has been suggested by Chacko *et al.*¹⁰ that the khondalite belt may be representing Proterozoic fault-bounded basin that received much of its arkosic sediments from granitic high lands and deposited over the pre-metamorphic equivalent of massif charnockites (tonalitic orthogneiss). The incipient charnockite-forming event appears to be a late Proterozoic event (540 my (ref. 9)). Previous morphological study of zircons of khondalites and massive charnockites suggested respectively sedimentary and magmatic origin for the rock types¹². In this study we have selected an incipient charnockite from Nedumangad (Lat 8°42'; Long 77°02') and a massive charnockite 2 km east of Vadasserikara (Lat 9°21'; Long 76°50') to study the morphological characters of zircons and to verify the data against the prevailing views that (a) charnockites in southern Kerala are magmatic¹³ and (b) the massive charnockites are igneous and incipient charnockites formed from metasediments^{9,10,14}.

The massive charnockite was collected from the northern margin of the Achenkovil shear zone and at the northern terminus of the KKB. The rock is medium grained with greenish to greyish black colour. It occurs as a large massive body with no diagnostic structural element in quarry exposures but the weathered portions reveal gneissic layering. The rock is made up of a typical granulite facies assemblage of quartz + alkali feldspar + plagioclase (An₄₀) + hypersthene + hornblende + magnetite and zircons, set in a hypidiomorphic texture. Graphite and garnet are absent.

The incipient charnockite was collected from a fresh active incipient charnockite quarry near Nedumangad. The charnockite is interlayered with graphitic garnet biotite gneiss. Sillimanite-bearing pelitic gneiss (khondalite) occurs few metres away but in the same interlayered sequence. Distinct planar fabric defined by garnet and biotite is present in the charnockite. No cross cutting relation between gneiss and charnockite, which could be assigned to an igneous process was observed. The field relationships between gneiss and charnockite are similar to those seen in incipient charnockite localities of south Kerala^{9,14}. The rock is coarser grained with a mineralogy of quartz + K-feldspar + plagioclase (An₃₅), garnet + biotite + hypersthene + graphite + ilmenite and zircon set in a homogeneous granoblastic texture.

Zircon was separated following the method of Murthy *et al.*¹⁵. The work involved crushing of samples to -60 mesh, washing to eliminate fine powder fraction and heavy mineral separation at 1.4 amperage with forward slope of 15° and side tilt of 20° using isodynamic separator. The nonmagnetic concentrate containing zircon was treated in methylene iodide and clericii solution.

Table 1. Morphological data of zircons

Charnockite	Colour	Euhedral/ terminally rounded	Rounded	Over growths	Metamict	Inclusions
MC 278: Massive (ortho)	Colourless	97.5	2.5	8	1.5	53.5
IC 279: Incipient (para)	Colourless to light brown	75	25	3.5	2	34.5

Table 2. Statistical data on zircons

Charnockite	\bar{X}	\bar{Y}	N	SX	SY	r	a	θ	σa	Dd
Massive	0.3027	0.1162	200	0.1185	0.0376	0.5345	0.3173	17°36''	0.0189	13.69
Incipient	0.2009	0.1137	200	0.0891	0.0429	0.0457	0.4815	25°46''	0.0340	35.51

Final purification was made by hand picking under stereobinocular microscope. Two hundred unbroken zircons were used for statistical morphological studies (Tables 1 and 2). Statistical computations are based on the measurement of mean length (\bar{X}), mean breadth (\bar{Y}), standard deviation of length (SX) and breadth (SY), standard error of slope (σa), coefficient of correlation (r) and relative dispersion (Dd).

Zircons generally occur as tiny crystals in very minor quantities in both the rocks. They are translucent and colourless, which are characteristic of granulite-facies varieties^{16,17}. Minor occurrence of hyacinth coloured varieties is noticed. Four types of zircons are noted in both the rock types, viz. euhedral, terminally rounded, subrounded and rounded. Globular and rod-like inclusions are fairly common in zircons but overgrowths and zoning are uncommon.

The statistical parameters of zircons are given in Table 2. In massive charnockite, zircons vary in length from 0.11 to 0.8 mm and breadth from 0.05 to 0.29 mm. Up to 73% is terminally rounded and does not show any angle between length and C-axis. 25% of zircon population is made up of euhedral crystals (Figure 1a). Overgrowths are negligible. The size-frequency study, following the method of Larsen and Poldervaart⁶ suggests length maxima, depicting polymodal prominent peak at 0.225 mm and breadth maxima depicting a monomodal, prominent peak at 0.1 mm (Figure 2a, b). The elongation curve is sharp monomodal with a maxima at 2.5 mm (Figure 2c).

In incipient charnockite a high percentage of rounded zircons (~25%) was noted (Figure 1b). Euhedral and terminally rounded zircons make about 18% and 57% respectively. Overgrowths are seen in about 4% of the zircons. Variable angle between length and C-axis is noted in the rounded zircons.

The data of length (0.08–0.54 mm) and breadth (0.05–

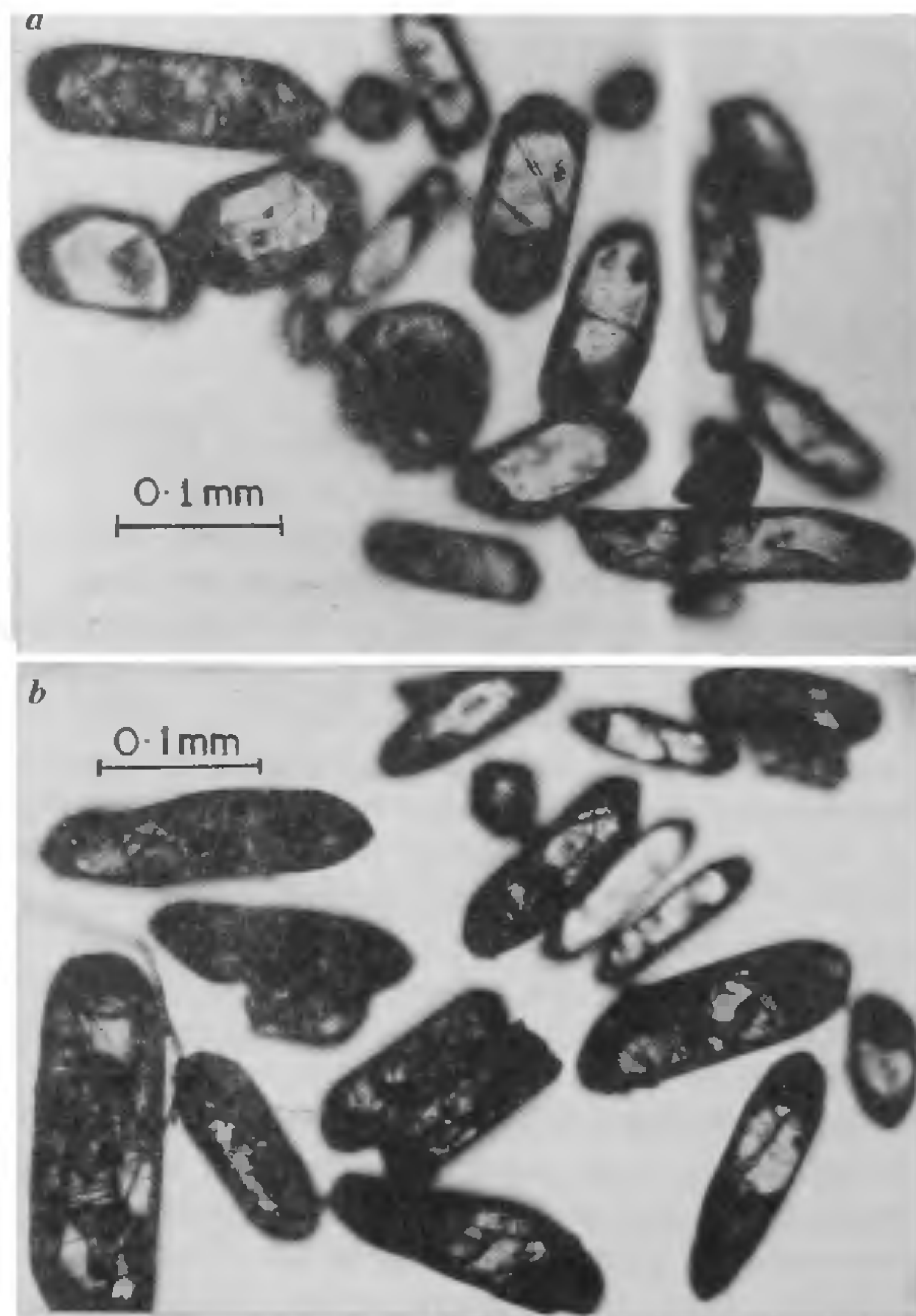


Figure 1. a, Zircon crystals from massive charnockite. Note the corroded and terminally rounded margins and euhedral shape. b, Zircon crystals in incipient charnockite. Observe that a majority of zircons show rounded and a few show euhedral shapes.

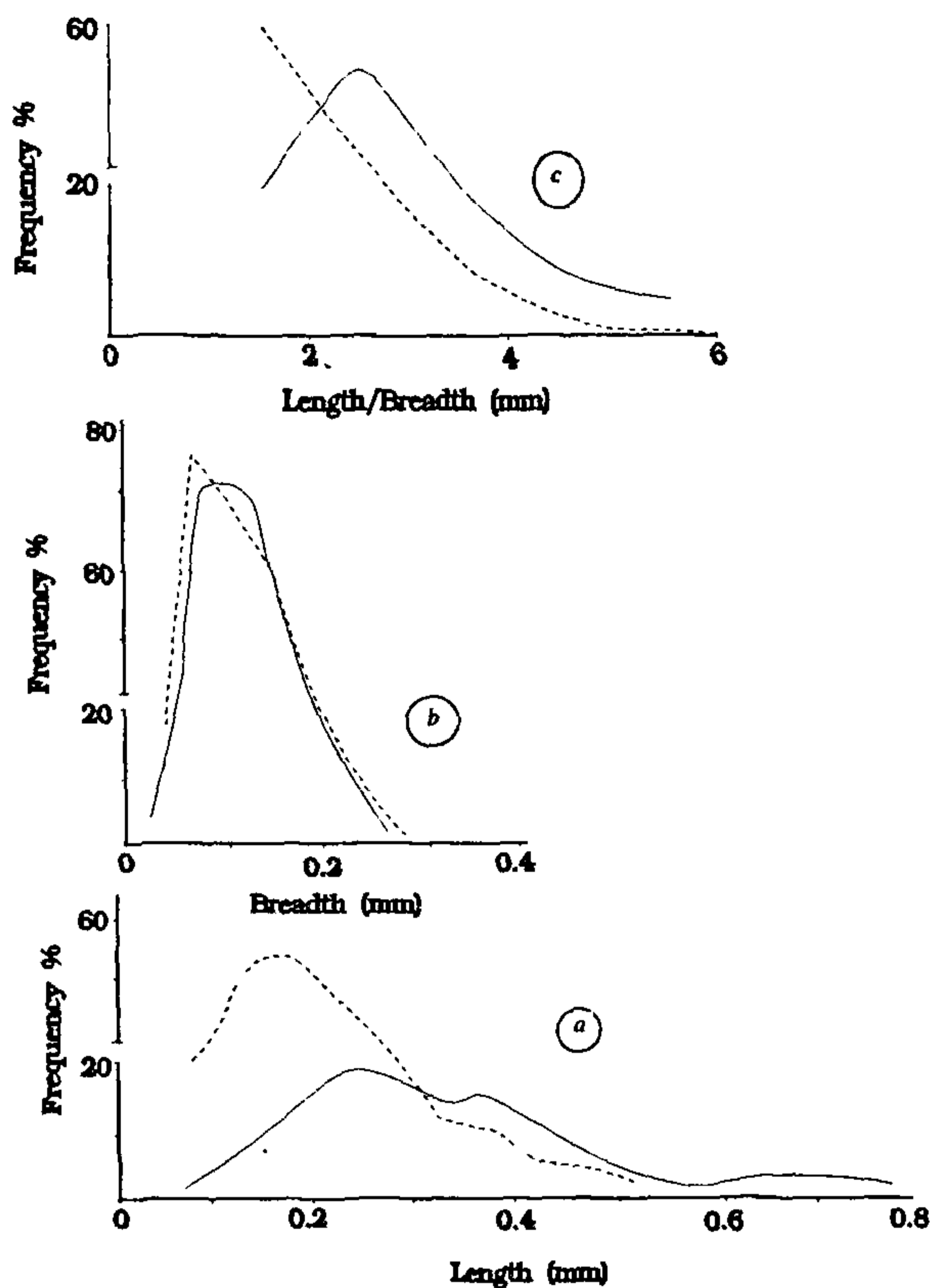


Figure 2. Size frequency data of zircons of massive (unbroken line) and incipient charnockite (broken line) plotted against (a) length, (b) breadth and (c) length/breadth.

0.32 mm) analysed according to Larsen and Poldervaart⁶ suggest polymodal length maxima at 0.175 mm, and sharp monomodal prominent peak with a breadth maxima at 0.75 mm (see Figure 2a, b). Elongation curve is sigmoidal (Figure 2c).

A statistical method of treating zircon by reduced major axes (RMA) technique was developed and tested by Larsen and Poldervaart⁶. It is considered to depict the growth trend line of zircon. This trend line also provides a means of evaluating any differences between the rock types. This method follows a simple principle that zircons crystallized from the same magma will have similar physical properties and follow a linear distribution in length-breadth scatter diagram. To test the differences between the incipient and massive charnockites, the reduced major axes of these rocks have been plotted (Figure 3) following the method of Larsen and Poldervaart⁶. The visual comparison of RMA shows significant variation with different slopes for incipient and massive charnockites. The variation in the slope decreasing with increase in elongation of zircons shows that these rock

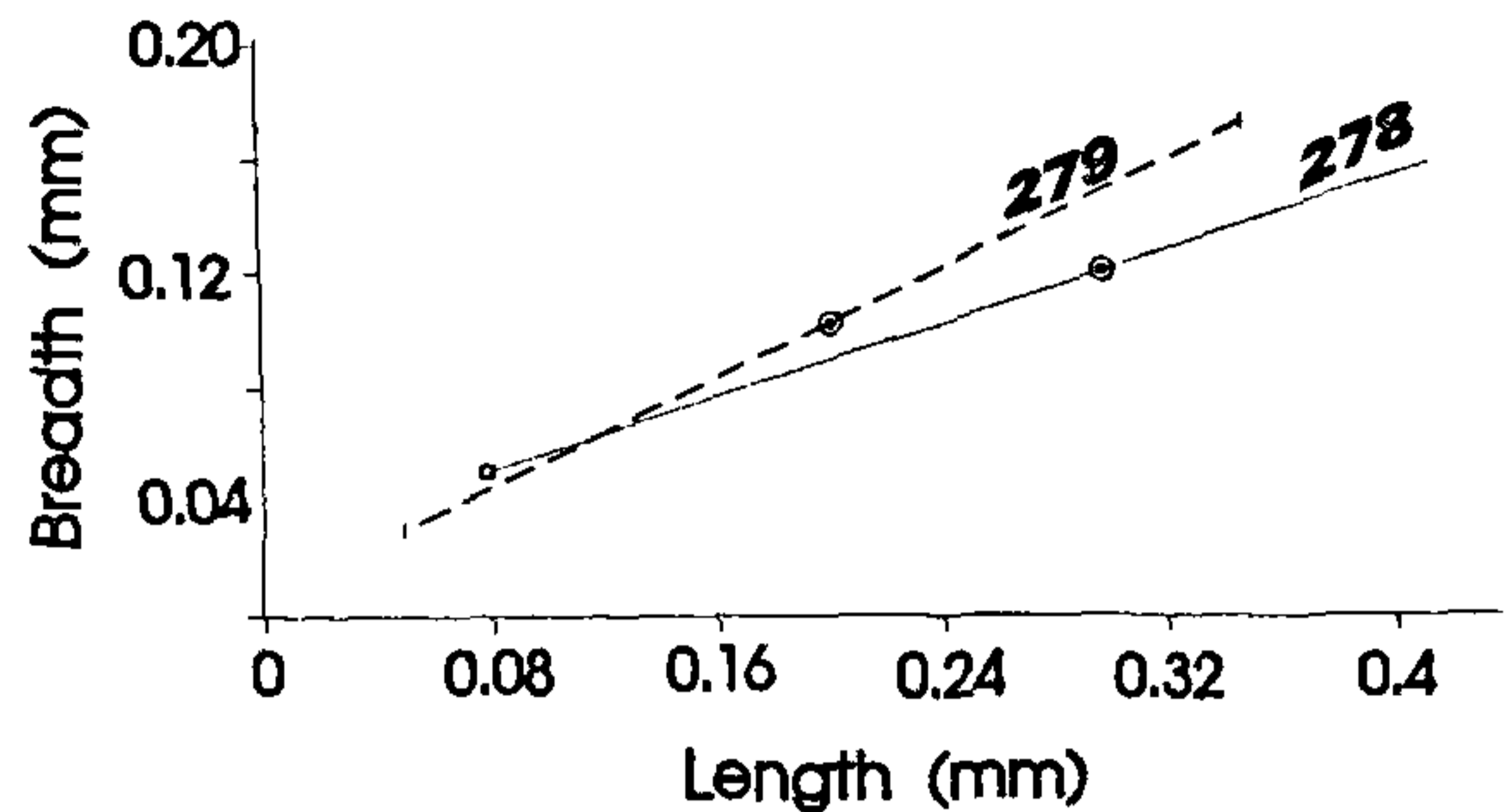


Figure 3. Reduced major axes of length (mm) and breadth (mm) measurement of massive (unbroken line) and incipient charnockite (broken line).

types belong to diverse source region and have entirely different nature of origin. The noncomparable RMA slope position of euhedral and rounded zircons of incipient charnockite suggests dominant detrital nature and the rounding of zircons as due to sedimentary processes. However, similar tests on the zircons of massive charnockite suggest a comparable RMA slope, suggesting the rounding of zircons of these charnockites to be due to corrosion¹⁸.

From the present study it is clear that the characteristics of zircon in massive charnockite are in contrast to those in the incipient charnockites. Higher percentage of euhedral zircons is seen in massive charnockite whereas the zircons of the incipient charnockite are detrital in character and have relatively greater percentage of rounded zircons. This suggests that the precursor rocks of incipient and massive charnockites may have formed in different environments. Terminally rounded nature of zircons ascribed to corrosion, and relatively higher euhedral zircons in massive charnockites favour igneous origin. Moderately well rounded and a few terminally rounded zircons in incipient charnockites suggest diverse source and some of them to be reworked. Further, the zircons from massive charnockite have significantly greater length/breadth ratios than the incipient charnockite zircon varieties. The low length/breadth ratios of zircons of incipient charnockite are consistent with a sedimentary protolith for this rock type. Although less, significant presence of euhedral zircons and terminally rounded zircons in incipient charnockite supports the contention that the immediately adjacent high land areas where massive charnockite are abundant¹⁰ provided the detritus to the depositional basin, whereas the rounded zircons suffered a long distance transport.

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