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GEOLOGICAL, PALYNOLOGICAL AND PALEOMAGNETIC INVESTIGATIONS ON LATE PALEOZOIC VARVITES FROM THE PARANÁ BASIN, BRAZIL

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ABSTRACT

Rhythmites associated with glacial diamictites of the Itararé Subgroup from three localities in the Paraná Basin, at Itu (São Paulo), Rio Negro (Paraná) and Itaú (Santa Catarina) quarries, display a set of sedimentary features analogous to that of Pleistocene and Recent varves, thus indicating the action of similar processes during their deposition. They may be considered as fossil equivalents of varves deposited by turbid underflow currents in glacial lakes or other suitable body of water and thus, may be called varvites.

Independent palynological analysis of the two lithologic components of couplets from Itu and Itaú, demonstrated that spores and pollen are mostly concentrated in the lighter coarser bands, the thinner darker ones being practically barren of plant elements. Repetition of this pattern in couplets of different stratigraphic position seems consistent with the concept of annual (seasonal) control of deposition of couplets, whose microfloral content reflects the varying availability of plant material throughout the year.

Spectral analysis of thickeness variation and of paleomagnetic data obtained for three long and continous series of couplets evidenced a strong correlation between periods that may be interpreted as indicative of the seasonal nature of the rhythmites. Additionally, a good agreement has also been shown by the spectra derived from data on solar activity (sunspot number) and the thickness and paleomagnetic results, and between the latter and the geomagnetic spectra. The consistence found does also support the idea that the rhythmic variation of the sediments is climatically controlled, according to an annual depositional cycle.

Environmental contraints for the formation of varves imply that the Itararé rhythmites were deposited in fresh water bodies, either in glacial lakes of several types or possibly also in marine basins, near the coast, under the influence of wet-base glaciers.

INTRODUCTION

Varve-like rhythmites, often called varvites, are a conspicuous though not common lithology within the diamictite-bearing sequence of the Itararé Subgroup (late Carboniferous-early Permian) in the Paraná Basin of Brazil (Rocha-Campos, 1967).

Studies on these rhythmites now in progress are directed towards the following objectives: a) their identification as seasonal rhythmites and thus as analogues of Pleistocene varves; b) determination of their geometry and stratigraphic (spacial) relationships with other sediments of the Itararé Subgroup, particularly, with the diamictites for which a glacial origin can be unequivocally proved; c) establishment of their origin and environment of deposition (sedimentary model(s); and d) their utilization as records of the sedimentary and paleoclimatic history of the late Paleozoic glaciation. Though also potentially useful for correlation, the sporadic occurrence of these rocks within the Itararé Subgroup makes this possibility highly improbable.

In the present report preliminary results of geological, palynological and paleomagnetic observations made on three main rhythmite occurrences geographically and stratigraphically widely separated within the Paraná Basin are summarized and their bearing on the sedimentation and paleoclimatic interpretation of the rocks are briefly commented.

GEOLOGICAL SETTING AND SEDIMENTARY FEATURES

Rhythmite localities discussed in the present report are: a) Itu quarry; b) Itaú quarry; c) Rio Negro quarry. Their approximate geographic and stratigraphic positions are shown on Fig. 1.

Itu quarry. The rhythmite section at Itu, at least 28 m thick (Fig.2), forms the upper part of a sequence that starts at the base with diamictite intercalated by elongate, irregularly shaped, contorted bodies of sandstone, followed upward by fine, cross-bedded sandstone with thin interbeds of diamictite. Couplets are made up of lighter beds of fine sandstone/siltstone and darker silty-clay laminae. Their total number could not be established, but on the several quarry faces (Fig.3) a continuous series of at least 260 pairs have beem counted and measured (Ernesto, 1977). They vary in thickness from about 50 cm at the bottom, diminishing upwards to about 1.5 cm or even less. This general thinning-upward trend of the rhythmite couplets includes much fluctuation and is mostly due to the variation in thickness of the lighter beds, that of the darker ones remaining more or less constant. A parallel trend is also shown by the grain size of the lighter beds which are predominantly of fine sandstone at the bottom passing upwards to mostly silt.

The Itu rhythmite is characterized by sharp contacts between the uppermost dark laminae of couplets and the lowest lighter bands of the overlying pairs; sharp but transitional boundaries between darker and lighter bands of a single couplet; and presence of silt/clay inside the lighter bands and of sand within the darker laminae. Other common sedimentary structures are: plane parallel lamination, multiple graded beds/laminae, and isolated ripples or ripple drift cross-lamination. Occurrence of the sedimentary structures seems to vary with the change in couplet thickness and granulometry. Invertebrate (arthropod) trails of several types are commonly seen on the upper surface of the darker layers and rafted clasts up to few decimeters or perhaps up to one meter are of rare occurrence.

The environment of deposition of the rhythmite and associated beds of the Itararé Subgroup in the Itu area is interpreted as glacial terrestrial on the basis of: a) the nearby occurrence of glacially striated and polished roche moutonnés and pavement; b) the absence of marine fossils in the section; and c) the local stratigraphic setting of the rhythmite. The rhythmite itself is thouht have been deposited in glacial lake into which rafted clasts could have been contributed by icebergs. The association of the Itu rhythmite with other sediments (diamictite and sandstone) in a fining-upward cycle and the thinning upward trend shown by the couplet thickness may be explained by deposition under the influence of a retreating glacier front, increasing distance from meltwater source or from marginal deltas.

Itaú quarry. The Itaú rhythmite (Fig.2) occurs above a lower sequence of cross-bedded sandstone and thick rhythmite(?),and is disconformably overlain by channel sandstone and diamictite (Castro & Medeiros,1980). At the quarry, about 9 m of rhythmite including 127 pairs have been counted and measured. Couplet thickness varies from 32 cm to 1.2 cm (Ernesto & Rocha-Campos, 1979); in the lower two thirds of the sequence, couplets show only sporadic increase in thickness, but in the upper third a thickening upward trend is apparent (Fig. 4).

Couplets are made up mostly of siltstone (lighter bands) and clay (darker bands). As in the case of the Itu rhythmite, variation in thickness of the pairs is due to change in the lighter bands, the darker ones remaining relatively constant. Besides the plane parallel bedding, other sedimentary features commonly associated with the Itaú rhythmite are multiple, both normal and reverse graded laminae and micro-cross lamination in the lighter bands, and normal grading in the darker ones. Inclusions of fine sand or of clay partings may be seen respectively in the darker and lighter bands.

A characteristic feature of the Itaú rhythmite is the presence of numerous zones or lenses of chips or pellets of clay, sandstone and diamictite that may occur sporadically within the lighter bands.Rafted clasts up to a few decimeters and arthropod trails of several types are not rare in the Itaú rhythmite. No clear relationship was found between occurrence of sedimentary structures and couplet thickness.

The Itaú rhythmite has been interpreted as part of a deltaic complex prograding over glacial marine sediments in the Rio do Sul area. The general environment of deposition is therefore considered as mostly continental (Castro & Medeiros, 1980). The thickening upward trend shown by the couplets at the quarry might reflect in increasing proximity of the glacier front or meltwater source.

Rio Negro quarry. At the Rio Negro quarry, a 30 m thick section of rhythmite and shale is locally intercalated between two diamictite bodies(Fig. 2).

601 couplets have been counted and measured along the quarry face (Ernesto & Rocha-Campos, 1979).(Fig. 5.) They represent however roughly a third of the section exposed and the total number of couplets may be at least 3 times larger.

Couplets in this locality are very thin, varying from 2 to a maximum of 52 mm. No general trend of variation could be established by visual inspection and, except for the intercalation of a few exceptionally thicker pairs, the maximum and minimum thicknesses seem to remain about the same along the examined section. Granulometrically, all the couplets seem to be made up mostly of silt (lighter bands) and clay (darker bands).

Except for the plane parallel bedding very few other sedimentary structures could be identified in the rhythmite. Microclasts of different lithologies, pellets of sandstone and diamictites and very thin partings of clay and sand are widespread inside the couplets. Contact between darker and lighter bands is transitional within each pair. Erosional contact is evident between adjacent couplets.

Rafted clasts up to 2 m in diameter are relatively frequent within the rhythmite.

Marine influence during the deposition of the Itararé sediments of the Rio Negro area is indicated by at least two intercalations of shales containing marine fossils (Salamuni et al., 1966). Non-varved dark-gray shale immediately below and in transitional contact with the rhythmite at the quarry yielded poorly preserved marine microplankton; elsewhere in the Rio Negro area a marine shale was found to occur intercalated within a rhythmite stratigraphicaly higher in the section (Salamuni et al., 1966). Marine fossils though have not been recorded in the rhythmite.

A glacial marine origin for the diamictites and associated sediments of the Rio Negro area is thus likely. The occurrence of numerous contorted and disrupted beds and flow structures in the diamictites of the area is consistent with this interpretation.

Since experimental and geological evidence indicates that formation of typical clastic varves is normally restricted to fresh water conditions, due to the flocculating effect of salt, under marine conditions, occurrence of varve intervals within a marine sequence would thus be possible only during periodically drastic reductions of salinity in the marine water body, a situation that might theoretically occur in the proximity of a glacier front sporadically discharging large volumes of melt water near the coast (Carey & Ahmad, 1961). Such an environmental picture is envisaged to explain the formation of the Rio Negro rhythmites. The relatively frequent occurrence of rafted clasts indicates that floating ice was present in the basin of deposition.

PALYNOLOGICAL ANALYSIS

Histograms of Fig. 2 (Rocha-Campos & Sundaram,1981) summarize the results of palynological analysis done separately on the lighter and darker bands of rhythmite couplets of the Itu and Itaú rhythmites. In analogy with what happens with Pleistocene varves (Terasmae,1963), a marked difference was found in the palynomorph content of the couplets examined. Most of the pollen and spores of the couplets are concentrated in the light colored layers the darker ones being pratically barren. The same pattern of distribution was found for the palynomorphs from the Rio Negro rhythmite though the small number of grains counted were insufficient for statistical treatment.

Additional comparison between the Pleistocene varves and the late Paleozoic rhythmithes can be made with regard to the pollen/spore "spectra" found in the couplets. In spite of the well known limitations in the paleobotanical and paleoecological interpretation of the fossil microfloras, it seems that two different types of vegetation did exist in the vicinity of the depositional basins. A pteridophytic vegetation, comprising lycopods, sphenopsids and filicales probably occupied a low ground or swamp area, while a nearby upland vegetation may also be suspected from the presence of monosaccate and dissaccate palynomorphs. A similar composition, including both dry upland and humid lowland forms has been found in the palynological assemblages obtained from Pleistocene varves (Terasmae, 1963).

PALEOMAGNETIC ANALYSIS

Parts of the three rhythmite sequences have been sampled for paleomagnetic analysis. In the case of the Itu and Itaú rhythmites an oriented hand sample was collected for each couplet and three 2.5 cm specimens from each sample were submited to paleomagnetic analysis. As the Rio Negro rhythmite couplets were too thin for individual sampling and measurement of magnetization, in general three or four pairs were measured together and their individual values interpolated.

The paleomagnetic analysis consisted of steps of thermal cleaning of secondary magnetizations with subsequent measurement of the remanence until a characteristic direction of magnetization, thought to be the primary one, has been obtained for each sequence.

Paleomagnetic data obtained are summarized in the right column of Figs. 3-5 where magnetic inclination and declination are represented for each couplet in the three sequences sampled. For comparison data on thickness of the couplets are also shown on these figures.

If the rhythmites are seasonal, as indicated by their geological and palynological features, paleomagnetic and thickness data are annual and thus suitable for spectral analysis. The series have been submitted to the maximum entropy method and results are summarized on Tables I and II.

Table I includes also for comparison the thickness spectrum of the Potreiro Grande rhythmite on basis of data taken from the literature (Delaney, 1964). (Fig. 6).

The Rio Negro series has been analysed only in an interval of 160 pairs, to be consistent with the length of other series. The paleomagnetic spectra in Table II represent results of the direction of magnetization vectors, instead of considering their two components (inclination and declination) separately.

There is good agreement of periods both in the thickness and paleomagnetic spectra and this may be interpreted as indicative of the seasonal nature of the rhythmite, since a close correspondence would be improbable if each pair, taken as representing an year period, would in fact correspond to a variable number of years.

A relationship between solar activity and the earth's climatic behavior is generally accepted and periodicities have been found for some climate-related parameters which are consistent with the solar activity spectrum. In this way, results of the sunspot number spectrum have been included for comparison in Table I. The consistency between these spectra seems to support the idea that the variation is climatically controlled according to an annual depositional cycle.

Geomagnetic spectra have been included in Table II and are in good agreement with the periodicity shown by the paleomagnetic data. However, it is not conclusive that paleomagnetic data directly represent geomagnetic variations, since the former shows oscillations larger than those exhibited by the earth's present magnetic field. The same kind of difference has been reported for Recent varves and it may be due to the influence of sedimentation conditions (rate, among others), on the acquisition of remanent magnetization.

In the present case, a clear relationship between sedimentation conditions and paleomagnetic data is not apparent from the simple visual inspection of Figs. 3-5; it is however suggested by the close agreement between data on Tables I and II.

An alternative explanation for that might reside in the supposed influence of solar activity on the geomagnetic behaviour. In this way, paleomagnetic results may be seen as a second parameter evidencing the annual nature of the rhythmites.

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CAPTIONS TO FIGS. & TABLE

Fig. 1 - Geographic and stratigraphic location of the samples.

Fig. 2 - Columnar sections at Itu, Itaú and Rio Negro and palynological content of the Itu and Itaú rhythmites. Explanation (columns): dots: sandstone; squares; diamictite; bars:rhythmite, circles: conglomerate; (histograms): A: lower dark band, AB: middle lighter band; B: upper darker band; 1: Spores; 2: Monolete; 3: Monossaccate; 4: Disaccate; 5: others.

Fig. 3 - Itu rhythmite: couplet thickness and paleomagnetic data.

Fig. 4 - Itaú rhythmite: couplet thickness and paleomagnetic data.

Fig. 5 - Rio Negro rhythmite: couplet thickness and paleomagnetic data. Bottom of section at lower left; top at upper right. Paleomagnetic measurements refer to the upper part of the section.

Fig. 6 - Potreiro Grande: couplet thickness.

Table I - Comparison of results of spectral analysis of thickness and sunspot number data.

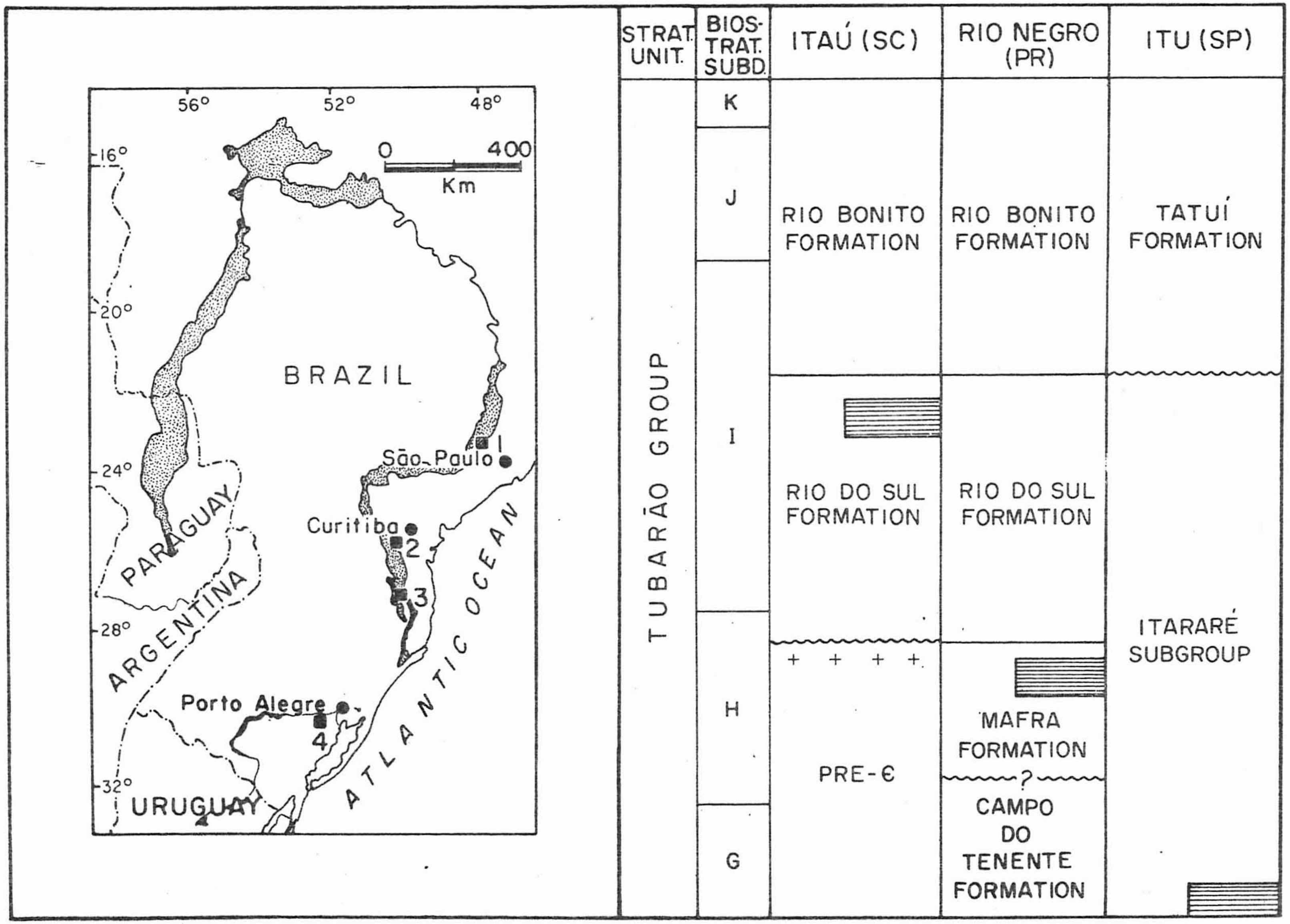
Table II - Comparison of results of spectral analysis of paleomagnetic and geomagnetic data.

TABLE I

						Period(years)		
ITU THICKNESS	40.0			11.5		8.3	6.5	5.6
OTREIRO GRANDE THICKNESS	43.5			12.0		8.6		5.5
ITAŬ THICKNESS		20.4		9.6			6.1	
RIO NEGRO THICKNESS	47.6		15.9	10.2		7.8	6.1	
SPOT NUMBER DATA aser-Smith,1972)			16.2	10.2		7.2	6.8	5.3
SPOT NUMBER DATA Currie,1973b)		23.6	14.7	11.2	9.9			

TABLE II

AGN. DIRECTION ITU		24.4		12.4	8.6	6.7	5.5
AGN. DIRECTION ITAŬ				10.6	7.9	6.5	
AGN. DIRECTION RIO NEGRO		21.3	17.9	9.5	7.1		5.3
EOMAG.SPECTRUM aser-Smith,1972)	35.2		16,1	10.2	7.0		5.1
EOMAG.SPECTRUM Currie,1973a)	60.5	21.4		10.5	7.1	6.07	5.15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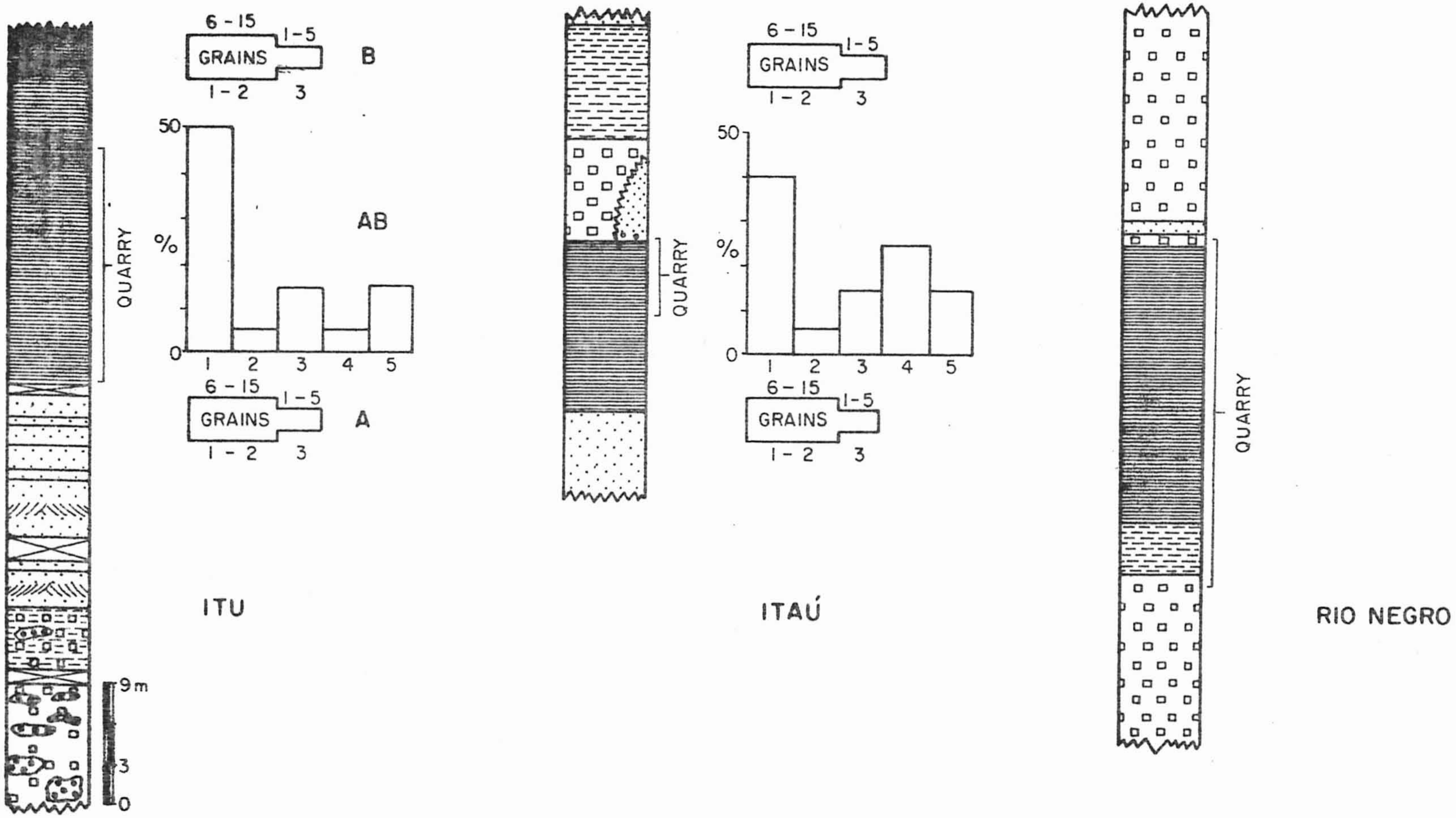

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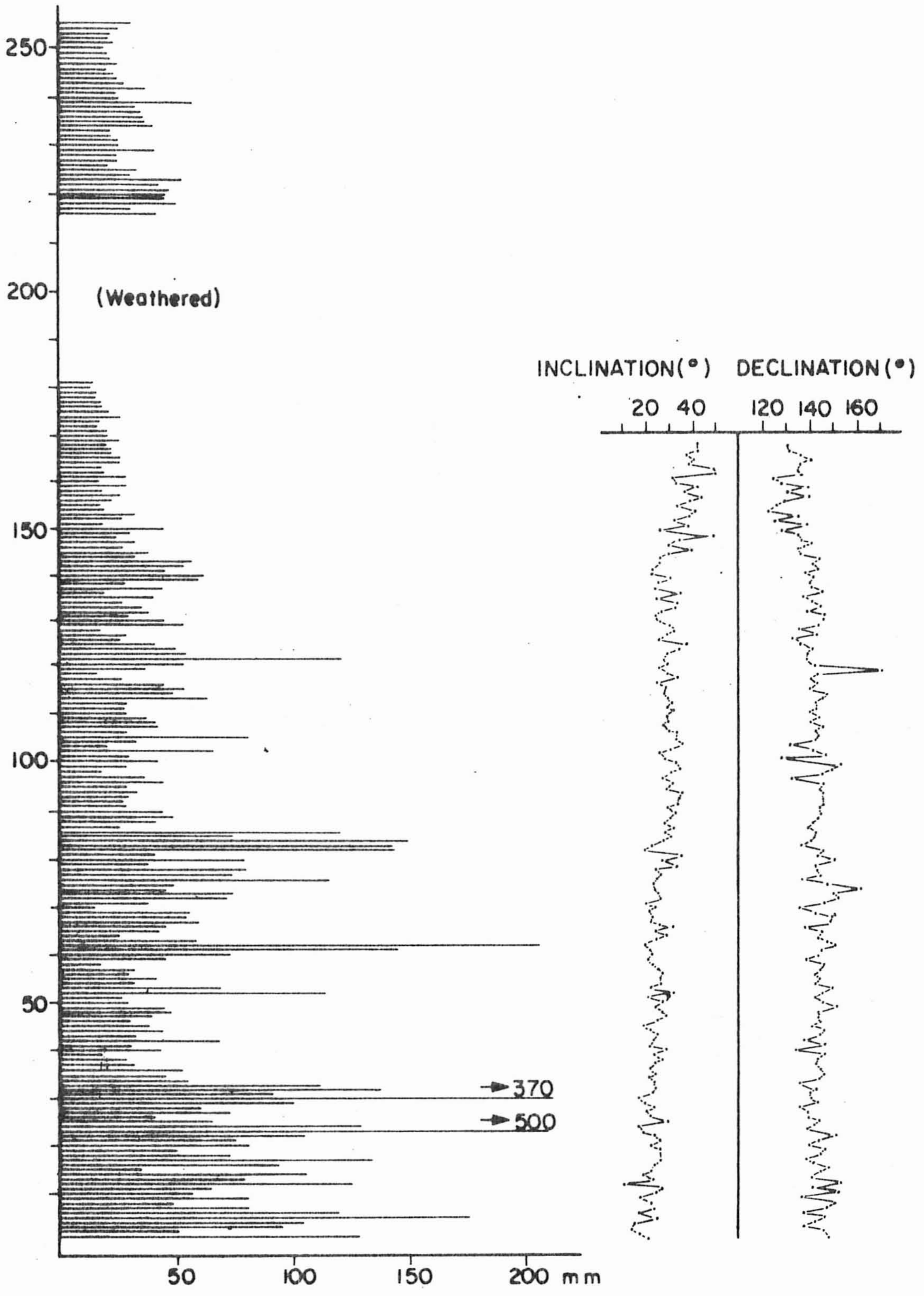
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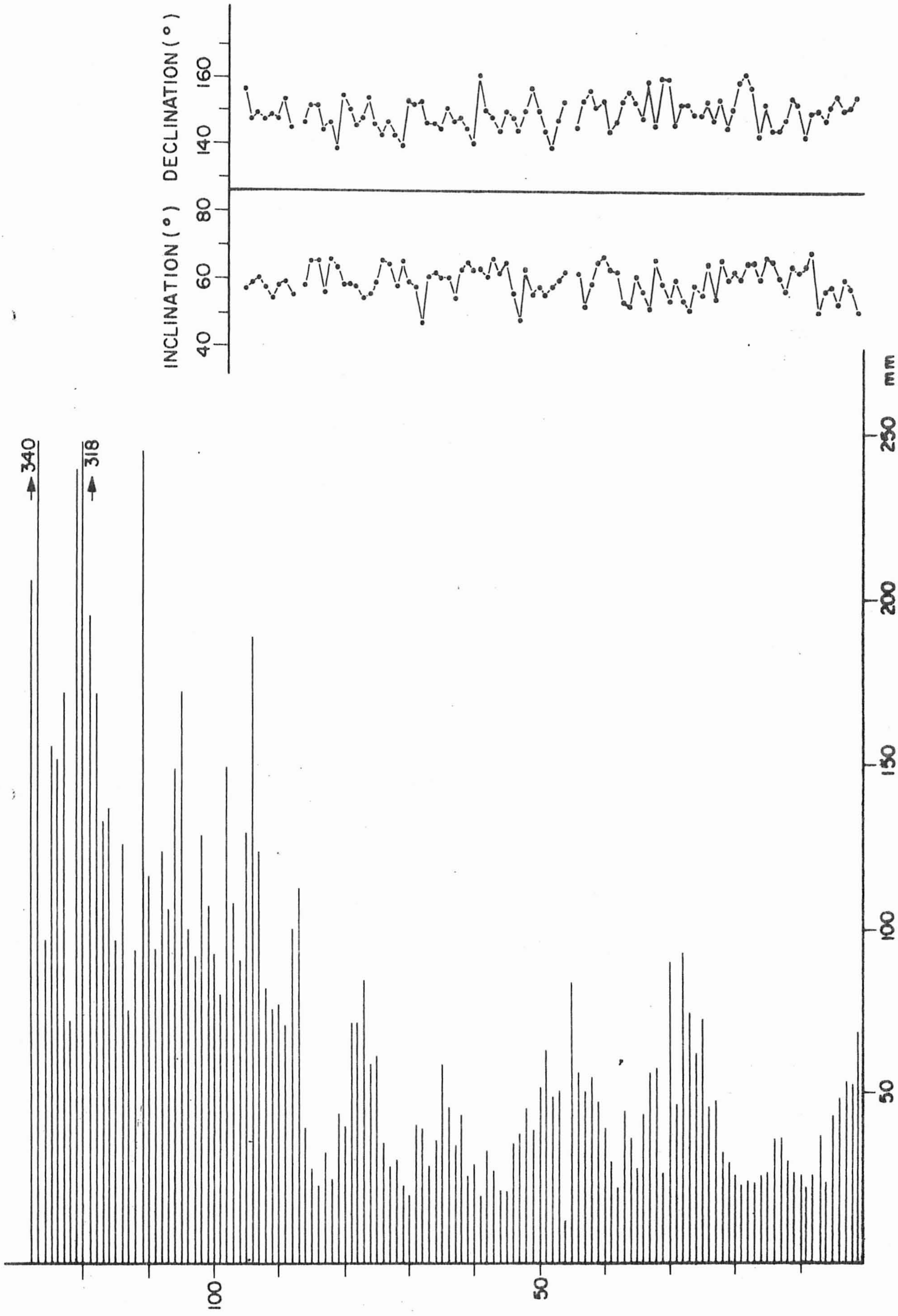
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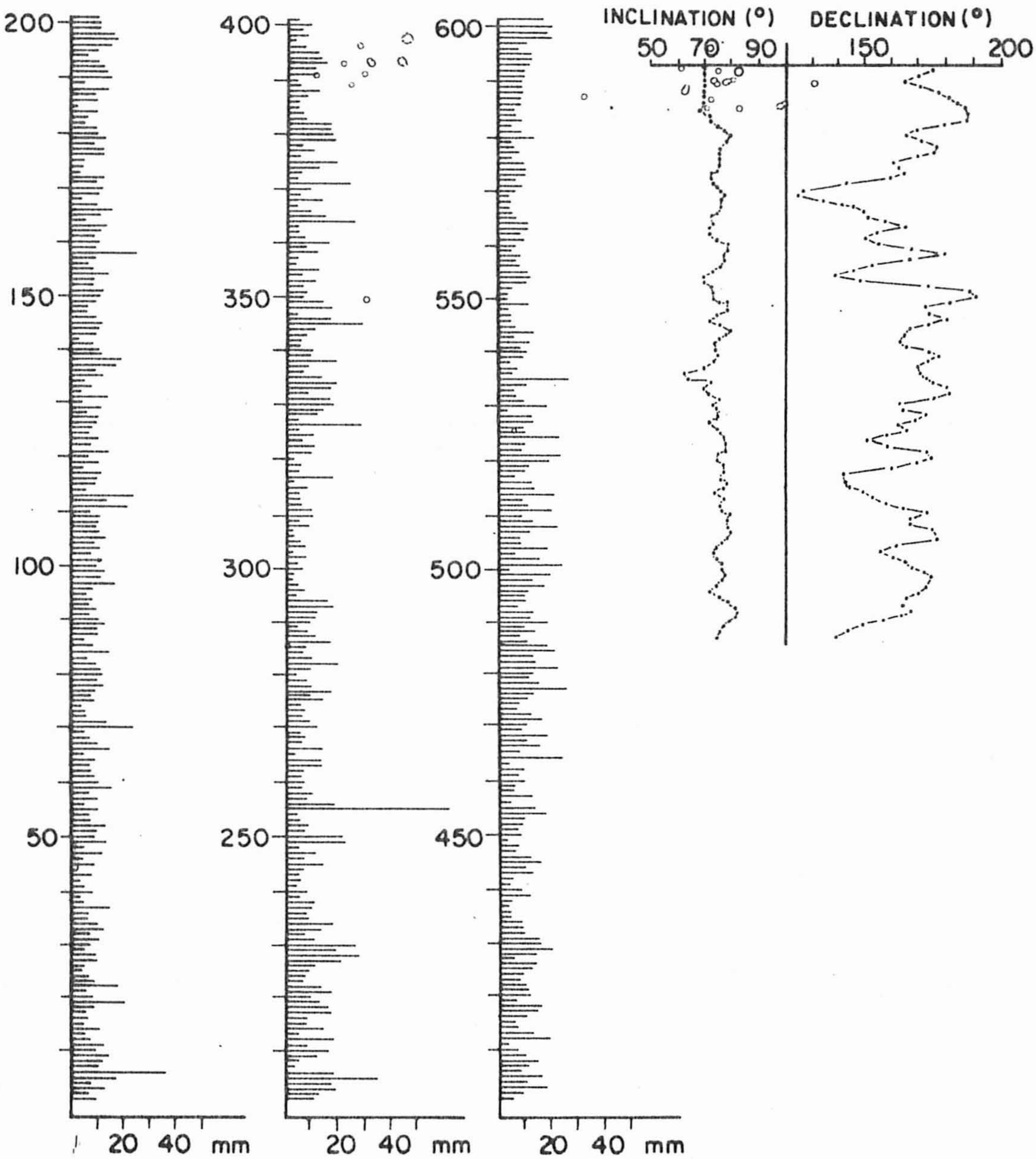
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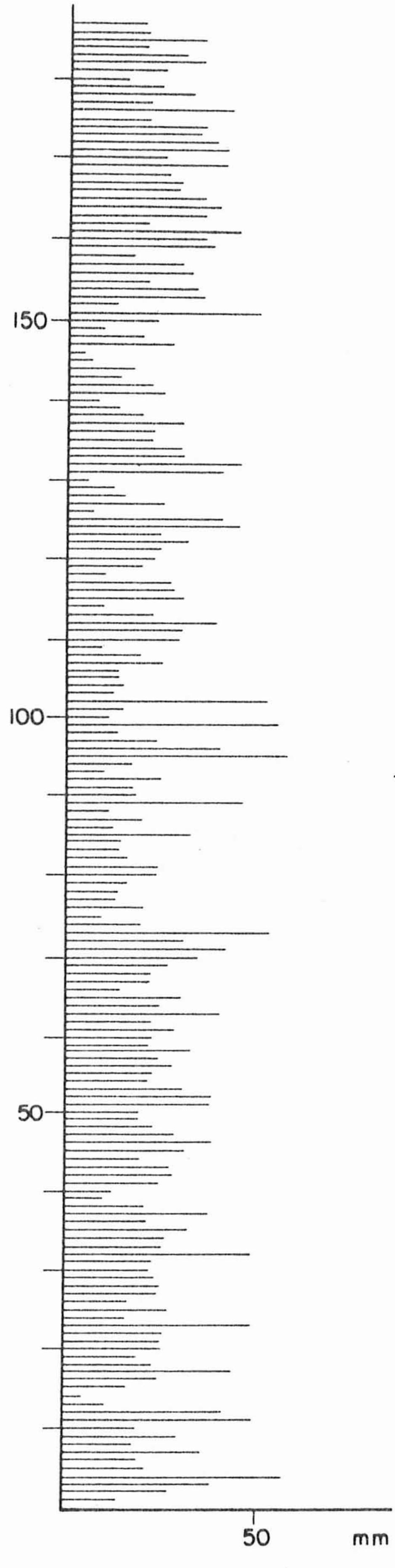
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