Title: Nummulites in the Collection of the University of Adelaide

R Dalgarno BSc

Dec 1959

Project: The object of the research was the preparation, examination and identification of ~~the~~ specimens of the genus Nummulites possessed by the Department.

Contents

The Form of the Test
Definition of Terms
Growth plan
Aberrancies
Septa and septal filaments
Septal flap
Marginal cord
Trabeculae
Pillars
Alternating Generations
Classification of the family.
Evolution of the genus Nummulites
Techniques
  Methods of preparation
  Measurement
  Illustration
Taxonomy

R Dalgarno Honours 1959
Supervisor: M F Glaessner

The Form of the Test:

Nummulites are lenticular, planulate or subglobular in form, and range in diameter from about 0·5 mm to 30 mm, with rare larger species. The test is planispiral, composed of many involute whorls, the diameter of the spiral usually being much greater than the thickness of the test measured in the direction of the axis of coiling. The chambers are numerous and are low and relatively uniform, and the septa representing successive chamber walls are convex in the direction of growth so that the posterior peripheral angle of the chambers is acute and the chambers are rhombic or sickle shaped, depending upon the curvature and spacing of the septa.

Each chamber straddles the preceding whorl and extends to the axial regions on both sides of the test, a condition described as equitant. The test then is completely involute and bilaterally symmetrical about the equatorial plane.

In an axial section the peripheral angle of the chambers is acute and the alar prolongations, or lateral extensions of the chambers are seen to be compressed so that the shape of the chambers is that of an inverted "V" with the main part of the chamber lumen in the apex.

Definition of Terms

The accompanying diagram FIG 2. illustrates the meaning of the terms, length, breadth and height of chambers.

The height is measured radially between the spiral laminae of successive whorls ie it is the vertical statistic of the chamber. The dimension at right angles in the equatorial plane of the chamber and from the outer surface of ~~of~~ one septum to the centre of the subsequent one, is the length of the chamber.

The breadth is measured in axial sections between the spiral laminae at the level of the periphery of the preceding whorl. In this way the alar prolongations of the chambers are excluded from the measurement.

The ~~ma~~ inclination of the septa is measured in equatorial sections by the size of the angle between the apertural face and a radius of the test, whereas the posterior peripheral angle is measured between the septum and a tangent to the periphery, at the posterior extremity of the chamber.

A whorl of the test is one complete revolution of the spire. It is most satisfactory to select an arbitrary diameter at which to define the limits of each whorl stop. In megalospheric individuals this line is chosen ~~the~~ to bisect both the protoconch and deuteroconch.

The expansion of the spire, or spire-pace, is sometimes expressed numerically as $\frac{\text{height of a given whorl}}{\text{height of the preceding one.}}$, both measurements including the outer spiral lamina.

Another method of expressing the tightness of the coiling is by the ~~sign~~ $\text{diameter}/\text{number of whorls}$. In both, higher values are obtained for ~~the~~ paucispiral or lax tests in which the spire expands rapidly.

Growth Plan

With the addition of each new chamber during growth, the whole of the external portion of the test is covered by a fine lamella of radially fibrous calcite which is continuous with the chamber wall. As there are a large number of chambers per whorl and the external parts of the test receive an added lamella at each phase of growth, a thickened spiral lamina results. This structure was at first interpreted as a "V" shaped wall of gradually expanding height, coiled in a plane-spiral and subdivided by partition-like septa.

However since Smout (1954) developed ideas already incipient in older works, it is no longer considered to be the primary structure of the test, since it is known to be comprised of the this series of lamellae each of which is continuous with a septum ocurring in that whorl.

The thickness of the spiral lamina at any stage of growth is determined by the number of chambers in the succeeding whorl, whereas the polar regions, since they remain external, have as many layers of shell material as there are chambers in the test and are thickened continuously with growth.

An indication of the structure of the spiral lamina is gained by the study of well oriented axial sections. Fine partings corresponding to the lamellae can be traced across the axis and the innermost lamella of any whorl (ie that which corresponds to the primary wall of the chamber cut by the section) may be traced through the axial region and found to correspond to a lamella in the middle of the spiral wall in the opposite side of the section. The subsequent lamellae of the spiral lamina are continuous with the septa of the chambers that comprise the half whorl succeeding the ~~one~~ chamber first considered.

When first formed each chamber ~~has~~ is only one lamella in thickness and the strengthening is due to the lamellae corresponding to the subsequent chambers of the whorl. For this reason the last formed chamber of the test is rarely preserved and few observations have been made of the aperture of nummulites. Grimsdale & Smout 1949 record that N planulatus and N variolarius appear to have no real aperture but only a series of pores at the base of the apertural face. This part of the chamber is resorbed when a new chamber is added and a basal foramen, a slot-like communication between internal chambers [illegible] test results. This structure, the intercameral foramen, [illegible] invariably present and may be seen at the base of the septa in equatorial sections.

Nummulites planulatus, which has rather upright septa, yields instructive preparations if axial sections of well preserved specimens are cut and left thick so that a complete ~~section~~ septum showing the interiomarginal foramen is preserved in the section.

The spiral growth pattern as seen in equatorial section, is normally very regular, and varies from very tight to relatively lax eg. compare the microspheric generations of N planulatus fig 4 and N laevigatus fig 7. The former has short chambers which increase rapidly in height whereas the latter species possesses long, low chambers which remain constant in proportion in successive whorls.

Irregularity of coiling is a noticeable feature of certain species particularly amongst the larger ones. Thus some species more than others, would seem to have been affected by external variations of the environment, with the result that they show great differences in the dimensions of successive whorls.

The rate of expansion of the spire is related to the shape of the chambers which is best illustrated by the curvature, height and facing of the septa as seen in equatorial sections.

In most species the relative proportions of the chamber dimensions change little during growth, however a change to laxer or tighter coiling during ontogeny is found in several species. In microspheric forms it is common for a phase of even expansion to follow an initial lax or rapidly expanding spire, and for the last few whorls to be comprised of very low long chambers with a consequently poorly developed spiral lamina.

Specimens which show this condition can be accepted as representing fully grown individuals which are not seriously decorticated.

Change in chamber shape which is observed in ontogeny and also in the phylogenetic development of a group (such as in the series N. planulatus, N. laqutanicus, N. laevigatus, N. brongniarti), FIGS 5-7 can occur without any change in the structural plan of shell deposition, since the newly formed chamber is simply in the nature of a lumen between the last and next formed lamella

Aberrancies of Growth:

Incompletely formed or aborted chambers are commonly observed, sometimes in groups of two or three, but more usually single malformed chambers are found and these do not result in any irregularity of the subsequently formed spiral lamina.

Regeneration is also commonly observed and it sometimes results in a multiple spire. The whole test, including the damaged portion is simply enclosed by the subsequent lamella and two chambers may be formed at each subsequent period of growth. One series of chambers may commence from the damaged region of the test and the other series is the normal spire which continues to grow normally when the final chamber remains undamaged.

The spiral laminae are thinner where a double spire or intercalary whorl is present because the surface of the test is exposed for a fewer number of instars. Multiple spires are reported to be fairly common in some of the larger species of nummulites, such as N gizehensis and N perforatus. Several specimens of the latter species in the collection possess them.

Smout 1954 describes their manner of formation where a double lumen is formed in one lamella and subsequently growth proceeds from each point. The second lumen apparently commonly occurs above and behind the true chamber and as growth proceeds the outer spiral series falls further behind the original series due to the larger circumference. This also means that the outer wall of the lower spire is exposed for an increasing number of instars and the spiral walls therefore become progressively thicker.

Septa & Septal filaments.

The lateral parts of the septa, or the walls between the alar prolongations of the chambers of the outer whorl, leave a raised linear trace on the surface of the test. These are the septal filaments and they are normally easily revealed by slight decortication of the test, if the preservation is such that they are not visible. The use of a little dilute acid, or the removal of the outermost whorl by flaking it away with a blade, is usually quite satisfactory.

of shell deposition. Septa & Septal filaments (contd)

Consideration of the chamber lumen rather than the septal filaments themselves, has led to the recognition of the fact that the alar prolongations of the chambers of the species with complex arrangements of the septal filaments, are in principle subdivided into secondary chamberlets. In simple species the septal filaments continue completely to the axis but for these advanced forms with anastomosing and branching septal filaments it is suggested that secondary foramina provide intercommunications between the lateral chambers and also connection to the main chamber. (Smout 1954)

The terms commonly employed for the description of the septal filaments are the following; radial, as in Nummulites globulus (FIG 17), sigmoidal, falciform, meandrine, as in N. gizehensis, subreticulate as in N laevigatus, and reticulate as in N. intermedius.

In species with a sigmoidal or falciform pattern of the septal filaments, the chambers are essentially radial and extend from the poles on either side to the circumference but they are sigmoidal in polar view with a strong flexure directed backwards near the periphery. A. M Davies 1935 suggests the use of the term falciform where the opposing curve at the pole, present in sigmoidal forms, is absent.

The term meandrine is applied to that condition where the lateral portions of the chambers form parallel groups or series which abutt polewards against the outer septum of the previous bundle. Nummulites gizehensis and to some extent N planulatus also, provide a good example. FIGS 4, 8

The condition of the septal filaments which is described as sub-reticulate and which is illustrated by N. laevigatus FIG 1a,b,1d is a regular but relatively complex network covering the surface of the test. As the filaments pass from the poles to the periphery they appear to send lateral branches to the

adjacent filament. Frequently this branching takes place at the site of pillars which are very numerous along the septa.
Reticulate pattern is an extremely complex network between closely packed granules so that the resulting appearance is cellular. The individual filaments can no longer be traced in a radial direction.
Although the structural series starting with a simple or meandrine pattern of septal filaments, passing through sub-reticulate to the reticulate form appears to represent a gradual increase in complexity, there has as yet been no clear evidence presented which shows the origin of the reticulate group eg N. intermedius etc from sub-reticulate forms. However a new phylogeny of the reticulate nummulites presented by
* ~~Hattatore~~ Nagappa (1959) suggests that they are derived from the sub-reticulate form N. acutus.
The filaments are apparently imperforate and they frequently appear raised and ~~hay~~ hyaline. Thus the trace of the filaments of the outer whorl are visible on the surface of the test since the pores of successive lamellae apparently do not tend to spread over the underlying filament.

The Septal Flap.

The double septum found in all nummulites requires two processes for its formation. When a new chamber is added a process related to the lamella comprising the new chamber forms a covering which adheres to the apertural face of the previous chamber, thus forming a double septum. This is the septal flap of SMOUT 1954, Both Smout, & Reiss (Jan 1958) state that the structure wedges out laterally. They describe it as part of a lamella which lines the roof of each chamber and fuses with the edge of the foramen formed between the new chamber and

the previous one.
Reiss and Merling 1958 equate the septal flap with part of the tooth-plate. They describe the toothplate as extending from the intercameral foramen towards the cameral aperture in each chamber. It is attached to the axial and lateral walls of the respective chamber and the posterior part is bent upward to cover the distal face of the previous chamber, and after making a forward bend it coalesces with the peripheral part of its own chamber wall. It is this part of the toothplate which constitutes the septal flap. It is poreless but the roof of each chamber with which it is continuous, is perforate and the chamber walls likewise are perforated by fine pores.

A problem yet remaining to be solved associated with the double nature of the septum, is the extent in the umbilical direction that the septal filaments remain double.

The Marginal Cord.

All members of the genus possess the structure termed the marginal cord, which is easily recognized in equatorial and axial sections. It comprises the peripheral portions of the whorls and takes the form of an apparently continuous thickened spiral.

The structure of the marginal cord is detectable in equatorial sections, where it is seen that each successive septum is continuous with one of the lamellae which comprise the cord. It is herefore only a specialized part of the spiral lamina and it shows variable development in different species depending upon the number of chambers per whorl. Particularly in flattened tests some adjustment is necessary between the ~~primary~~ lamellae which comprise the spiral lamina such that they can accomodate themselves to the acute bend at the periphery of the whorls. This takes the form of thickening in the individual lamellae so that the differentiated marginal cord results. Since the calcite crystals remain perpendicular to the lamellae, radially disposed streaks result and these may easily be mistaken for canals.

Specimens of N. planulatus in the collection which have had several chambers removed show a pattern of longitudinal grooves running spirally on the outer surface of the marginal cord. These grooves bifurcate and anastomose with adjacent ones and it is probable that they result in the spiral & ramifying canals of the marginal cord reported by Carpenter and others. It is also recognized that the marginal cord lacks the normal type of perforations present in the chamber walls.

Hofker (1956) refers to the marginal cord of the nummulites as synonymous with a the "marginal canal" that runs peripherally near the lumen of the chambers in the spiral lamina. He considers that the genus Nummulites is characterized by only a ~~sgdep~~ simple type of marginal canal and that no members of the genus possess a marginal cord canal system as well developed as that occurring in Operculina complanata.

However under certain conditions of preservation the canals of the marginal cord are infilled with pigmented material such as compounds of iron, and these reveal quite highly developed canal systems in certain species.

Radial intraseptal canals pass between the lamellae of each septum and provide an interconnection between the spiral canals of successive whorls.

Hofker employed a technique of artificially infilling the very fine tubules of the canal systems with Canada Balsam and then dissolving away the calcite of the test using dilute acid.

Trabeculae.

Trabeculae are fine dendritic canalicular structures which can be seen in most species to extend forward across the chamber wall from the previous septum. They possibly represent fine branches of the intraseptal canals. In specimen 120 of the collection which shows these structures very well developed, some few appear to extend backward over the wall of the preceding chamber and others are seen to have their origin along the lateral parts of the septa. The tubules are clearly original since there are no perforations in the immediately overlying lamellae and the tubules are only present in the innermost part of the spiral lamina. For this reason they are most clearly observed on the inner surfaces of the chamber walls in equatorial sections or in partly decorticated specimens and thin sections because the pores of the subsequent lamellae tend to spread over and obscure the imperforate region.

Protoplasmic streaming, resulting in irregular radial grooves on the septal face and chamber walls and which are covered by the subsequently formed septal flap is the chief mechanism inferred for the formation of the radial intraseptal canals and their branches. Such a mechanism does not entirely explain the formation of canals, however. Thus trabecules normally extend forward from the septa and the transverse portions of the ramifying canals of the marginal cord cannot arise by a process involving burial of grooves.

Trabeculae have been considered homologous with the secondary septa of Heterostegina etc but it even appears doubtful that they represent the rudiments of the complex septal filaments seen in advanced nummulites.

Pillars; The surface of the test may be quite smooth in species which lack pillars eg N planulatus, however small nodes termed granules or pustules are observed in those species which have pillars developed.

The sculptural pattern which results from the spotting of the surface by these small granules is often regular in arrangement, following the septa and marginal cord of the inner whorls. The pustules vary in size a frequency in different ~~forms~~ species and their position with respect to the septal filaments is an important taxonomic character. Their diameters are usually of the order of 0.1 to 0.5 mms and they are commonly concentrated in the axial regions of the test.

In some species eg N. variolaria, there is a large structure in the axial position which is described as a polar pustule or polar plug.

In axial sections, granulations are seen to be the extremities of rod like or gradually expanding pillars, which persist for several whorls ~~remaining~~ remaining perpendicular to the spiral walls, and passing through several chambers to the surface.

Some of the pillars in the axial regions extend throughout the whole thickness of the test from the periphery of the first whorl to the surface.

Smout 1954 distinguishes inflational pillars as those due to local thickening along a line normal to the lamellae, with each lamella contributing to their thickening.

A second form of pillar is the incised form which appears as a granule on the outer surface, and differs from the more rounded pustules of the other form.

Many pustulate species probably have pillars of a simple inflational nature, or more commonly a compound inflational- textural pillar.

All pillars appear to be imperforate and are characterized by a hyaline appearance and striations normal to the lamellae.

Alternating generations in g. Nummulites:

It was early recognized in the study of nummulites that their distribution followed a pattern in which the characteristic forms of a given bed were always two in number, apparently of close zoological affinity. It was gradually recognized that several pairs of species were related in this way and actually represented alternative forms of the same species. Thus Nummulites elegans FIG 18 was placed in the synonymy of N. planulatus FIG and N. lamarcki FIG 1d FIG 19 was recognized as a synonym of N. laevigatus FIG 1abc

The smaller forms are characterized by a large embryonic apparatus or megalosphere and are designated the megalospheric generation. The larger forms have ~~no visible~~ a very small initial central chamber and are therefore designated the microspheric form.

In the megalospheric generation the initial chamber is usually spherical and the deuteroconch is smaller and hemispherical or may be little differentiated from the later chambers.

The two forms commonly show structural similarities which indicate their relationship to one another and by analogy with living species in which an alternation of schizont + gamont generations is known, it is inferred that the more numerous megalospheric individuals with the large nucleoconch represent the gamonts, whilst the others represent schizonts. For this reason they are sometimes designated the A and the B form respectively.

It appears that there may be several differentiated types of megalospheric individuals within the one species. This condition has been referred to as trimorphism although there may be more than two such distinct forms (polymorphism). Hofker has suggested that only the most differentiated of the megalospheric forms (ie those with the largest nucleoconchs) may represent the true gamonts.

In situations such as this where there is more than one size for the megalosphere of a species, the specimens with the larger nucleoconch have tests of a smaller diameter than the less differentiated ones.

Although in certain cases the proportions of microspheric & megalospheric forms of the same species vary considerably there is frequently a noticeable similarity in the shape of chambers and the rate and regularity of the spire, especially when the megalosphere is small. This, taken with the occurrence of the two forms together in the one bed, is sufficient evidence to group the two in the one species.

On the other hand in species where the megalosphere is very large with respect to the test, there is often ~~little~~ less resemblance to the microspheric generation which in extreme cases may be many times larger.

Microspheric forms may show modifications of the chamber shape in the last few whorls which are not observed in megalospheric tests. This is apparently explained by the fact that the smaller generation has not attained the minimal size necessary.

It seems clear that the normal proponderance of megalospheric individuals is attributable to the nature of the life cycle. It is only in rare cases, which are easily explained by differential sorting due to currents, that microspheric individuals are numerically more important than the other generation. eg. N planulatus & N laevigatus in England, where the microspheric forms predominate in contrast to the conditions applying elsewhere in the Paris Basin at the same time.

For nomenclatorial purposes species based on either form are excepted as valid. If a new species name is introduced into the nomenclature for the other generation subsequent to this, then it constitutes a junior synonym and is invalid.

Classification of the Nummulitidae.

For recognition of the genera within the family Nummulitidae it is desireable to prepare specimens illustrating both axial and equatorial sections. Examination of an axial section is normally sufficient to establish the genus concerned as the characters spire pace and number of whorls, together with the degree of involuteness of the coiling of the chamber lumen and spiral laminae, are fairly constant within the respective groups. However for those genera which include species with highly variable coiling such as Operculina & Operculinoides, the degree of involuteness of the spiral walls & chambers cannot be employed as taxonomic characters and examination of equatorial sections is more satisfactory. In this case the no. & inclination of the septa and the height and curvature of the apertural face are valuable characters when considered together with the spacing of the septa and the thickness of the marginal cord.

The problem concerning the delimitation of the genera _Operculina_, _Operculinoides_, _Miscellanea_ and other early forms, from _Nummulites_, is currently receiving consideration by Cole in America & Nagappa working in Assam.

Morphologically intermediate forms are known between several of these genera so that it will be only after a fairly comprehensive study of stratigraphically reliably dated material that the phylogeny & classification of this group is ellucidated.

Cole 1959 & Davey 1935 independently rejected the genus _Operculinella_ Yabe 1918 as they judge the type species to be synonymous with _Operculina venosa_. ~~Grimsdale & Smout~~ It has also been suggested that it is likely that the genus _Operculinoides_ Hanzawa 1935 based on the species _Nummulites willcoxi_ Heilprin, will be placed in the synonymy of _Nummulites_. Cole 1959, on the other hand inclines the place this species under the genus _Operculina_. This illustrates the difficulty which arises with a form which is morphologically intermediate between two genera, in this case _Nummulites_ & _Operculina_.

The genus _Nummulites_ is relatively clearly distinguished from _Assilina_ however, by the fact that the coiling of both the spiral walls and the chambers is completely involute in Nummulites, while Assilina is characterized by chamber lumina which are limited to the peripheral region. ie they are evolute and there are no alar prolongations to the chambers. There appears to be little overlap between the two genera and median sections reveal ~~the~~ a further constant character. This is the nature of the posterior peripheral angle of the chambers which is acute in Nummulites and approaches 90° in Assilina where the chambers are rectangular rather than rhombic in form.

Puri ~~has~~ has recently contributed a paper (1957) concerning the classification of the Family Nummulitidae. However the emphasis of this paper is on problems of nomenclature rather than the presentation of new evidence designed to assist in the clarification ~~one~~ of the delimitation of the genera. He erected two new sub-families splitting ~~a~~ up the large, and as yet incompletely understood, sub family Nummulitinae, into three groups according to a fixed morphological scheme based on few characters. His classification is not based strictly even on his own outline of the phylogenetic development of the genera of the Family and it would seem that his subdivision is not justified.

The phylogenetic development and differentiation of these early forms of Upper Cretaceous & Lower Eocene age constitutes and important problem in the study of this group.

From the study of early ~~N~~ nummulites it has been suggested that involute coiling of the spiral walls and chambers is the primitive condition, so that on this postulate Operculina-like forms are considered to have been derived from the early nummulite stock which are small and non granulate and possess simple radiate filaments and a rather lax spire.

There is however, no reason to reject the alternative that *Operculina* and *Nummulites* have a separate origin from an early form which may not have been characterized by involute coiling.
It is also possible that the *genus Operculina* is actually a polyphyletic group.
Earlier workers have recognized within the family three chief lines of development. The first is that leading from *Operculina* to *Heterostegina*, *Spiroclypeus* & *Cycloclypeus*, the second is the series of parallel lines of development ~~regr~~ recognized as the *genus Nummulites*, and the third lineage corresponds to *Assilina*. In addition there are the several other less important side branches or steps corresponding to the genera *Miscellanea* *Sulcoperculina* *Pellispira* & *Biplanispira*.

The Genus Nummulites.

The early workers, d'Archiac & Haime 1853 & ~~dlla~~ de la Harpe 1883 grouped the species of Nummulites according to a static and morphological scheme based on relatively few characters. In several cases these have later proved to be independently derived in different lineages eg. granulations appear in several quite separate species groups.
Since the important contributions of Boussac 1911 & Douvillé 1919 several workers have contributed valuable data on the classification of the genus, notably Rozlozsnik, Davies 1935 and more recently Schaub 1951. All these workers have attempted to classify the species according to their phylogenetic development. Schaub states that for such a scheme to be reliable classification must be based on as many taxonomic characters as possible and the study of samples collected

in stratigraphic order from richly fossiliferous and reliably dated sections, is necessary.

Thus the rapid divergence of some forms and other cases of parallel and convergent development can only be elucidated where the relative ages of samples are accurately known and the available intermediate forms have been collected.

The classification into ~~3~~ three chief lineages is summarized in Glaessner (1945), however more recently Schaub has adopted a slightly different scheme of classification into groups.

Nagappa 1959 shows a table of the phylogenetic development of certain species of the Nummulites in ~~North~~ the Middle East. It has certain important differences from the accepted classification, which indicates that the relationships of even some of the important groups of species are not ~~as~~ yet definitely established. Nagappa considers the reticulate group of nummulites to be derived from the subreticulate form N acutus.

In the older classification this group was considered to have an origin quite distinct from the sub-reticulate forms and to be more closely related the simple striate group N atacicus and N. striatus. Nagappa also shows N. acutus as of independent origin from N laevigatus from which it was previously considered derived and he groups N laevigatus close to N. gizehensis. This arrangement conflicts with Schaub's suggestion that N. gizehensis & N. boussaci are closely related and that gizehensis is therefore a continuation of the suggested evolutionary series N. praecursor – N. partschi – N lorioli – N boussaci – ? N gizehensis.

The one evolutionary series that seems quite clearly established by intermediate forms is that leading from N. planulatus, through N. aquitanicus to N laevigatus & N brongniarti. See FIGS 4, 5, 6, 7

It appears that the study of the group will soon be at the point where several reliable evolutionary series will be available for detailed study, leading to a refined basis for stratigraphic correlation.

Techniques.

Methods of Preparation:

Several species of nummulites split readily along the median plane due to a weakness arising ~~due to the~~ from the acute fold in the spiral wall at the periphery and the radiating calcite fibres.

The most satisfactory method of study is to prepare individual specimens separated from the rock matrix. It is desireable to select at least two specimens which are similar in appearance, as the cracking of a specimen frequently destroys its external characters such as external septal filaments & distribution of pustules.

The technique employed to crack specimens was to heat one side of the specimen, while supported by a wire guaze, in the cooler portion of a direct bunsen flame. Normally on removal from the flame an incipient crack will appear about the periphery. The specimen was then cooled suddenly by dropping into cold water in a shallow container.

If this treatment failed it was found useful to cleave the specimens with a fine blade.

Globose tests and those in which the chambers have become infilled and recrystallized, tend to shatter with this treatment and the only remaining method of exposing the equatorial plane is then to rub them down on a lap with an abrasive powder and to transfer to a fine hone near completion of the section.

This method suffers from the limitations which apply to rock sectioning, it is time ~~time~~ consuming and since the specimens are frequently those with poor preservation it often difficult to judge when it is best to cease grinding. Thus particularly in specimens with an uneven equatorial plane, the plane of the section only coincides with it in small areas and the resulting specimen is not of great value since the chamber shape and spire suffer distortion where the section is oblique to the median plasce.

Once the specimen was split and any fractured portions repaired with Canada Balsam, it proved most satisfactory to fix the cleaved fragments to a glass slide with the equatorial plane uppermost. In this way those specimens with chambers free of matrix are not infilled with the fixing medium as they are when the specimens are inverted. This simplifies illustration & study since greater contrast can be obtained by the placing of lighting to cast shadows of fine structures. It also proves very difficult to exclude air bubbles from the chambers when the newly cleaved face is dropped into the balsam.

Wherever practical the externally similar specimen was fixed adyacent to the prepared specimen and if application of several drops of acid did not reveal the filaments & pustules, several whorls were removed from the outer surface of a fragment of the cleaved specimen so as to reveal these structures on the fresh surface. This was accomplished by flaking off the surface laminae with a fine blade.

Measurements

Diameter & thickness of the tests were measured with a vernier guage & a pair of calipers.

Dimensions of the nucleoconchs were measured using a micrometer eyepiece in a mon-ocular microscope.

Spire pace measurements and chamber dimensions were read from drawings.

Illustration

The most satisfactory method of comparison is to draw the specimens ~~well~~ using a drawing mirror with the microscope. The lens system is not altered so that a fixed magnification of the drawings results (x 20)

Those specimens which were suitable were photographed using the Departmental camera with extension tubes and the prints enlarged such that the resulting illustrations fell into two groups with magnifications of x5 and x10.

Taxonomy

ORDER FORAMINIFERA

FAMILY NUMMULITIDAE Reuss 1862

genus Nummulites Lamark 1801

type species Camerina laevigata [Bruguière] 1792

= Nummulites laevigatus (Bruguière)

(Excepted as valid on the grounds of accepted usage Opinion 92 International Zoological Nomenclature Comittee decision 1945)

Material

~~Spec~~ SAMPLE NO.

1. Nummulites planulata Lk Cuise Lower Eocene. Numerous microspheric specimens and a few megalospheric tests.
2. N. planulata elegans Mont de Magny Ypresian, -mainly megalospheric forms. Alveolinids also occur in the sample.
3. Nummulites Selsey Bracklesham Beds. A single microspheric specimen
4. Nummulina planulata Paris Calcaire Grossier. A couple of specimens of each of the microspheric and megalospheric forms.
5. N. laevigatus Selsey Bracklesham Beds. Several specimens, both A & B forms represented.
6. N. laevigatus Lk. middle Eocene (No locality given) A sample of a dozen free microspheric specimens
7. N. laevigatus Trieste Eocene. Two microspheric individuals
8. Nummulina laevigata Gosport middle Eocene. (aff Nummulites aquitanicus) A single free microspheric specimen
9. Nummulites laevigatus Eocene Paris Basin The sample includes specimens referable to g. Assilina (both micro & megalospheric forms and Discocyclina. No nummulites present.
10. N. brongniarti Vicentin Bartonian (u. Eocene) stage Small sample from which both A & B forms ~~are~~ were easily freed from a limy matrix.

~~13~~.11 Nummulites aturicus typique, Fontaine de la Medaille, Montfort. Numerous megalospheric tests with a single fragment of a microspheric form.

13, ~~[illegible]~~ N. aturicus same locality. Slides show median section of megalospheric forms.

12 N. aturicus et var Bayonne Landes. This sample contains both microspheric & megalospheric individuals.

14 N. ~~atrica~~ perforata Menton, Slide showing equatorial section of a microspheric form

15 N. perforata D'Orb. Several ~~[illegible]~~ microspheric specimens from the same area, Menton.

16 } N. perforata Kesttoga Ventimiglia. These samples
17 } contain both microspheric and megalospheric nummulites.

18 } Nummulites globularia Cuise Lower Eocene
19 } Numerous megalospheric specimens. These are compared to Nummulites planulatus

20. Nummulites sp Kressenberg Bavaria. Numerous microspheric & megalospheric nummulites were freed from the rock matrix. Large microspheric Discocyclina also occur in the sample. This species appears to be referable to the group of Nummulites burdigalensis of Schaub.

21. Nummulites atacica Montolieu. The sample contains numerous small ~~[illegible]~~ tests, mostly megalospheric forms, many of which are apparently referable to Assilina, cf Assilina pustulosa. Rare nummulites are also present, both microspheric & megalospheric forms. These are not described.

22. Nummulites Vicentin. Numerous microspheric nummulites which are referred to N. aff intermedius. Numerous Discocyclina and a megalospheric ~~N~~ nummulitid unrelated to N intermedius.

? fabianii? (~~[illegible]~~)

23. Nummulina variolaria Whitecliff Bay Isle of Wight

24 Nummulites variolaria Calcaire Grossier

25 N. variolaria. Paris Basin. All specimens are of megalospheric individuals.

26. N. biarritzensis All specimens are microspheric forms

referable to the genus *Assilina*

29 *Nummulites sp.* from Gizeh. A sample of limestone from which megalospheric & microspheric nummulites were chipped free. These show no apparent affinities and apparently represent distinct species.

32. ~~Nlina~~ is *Nummulina striata* Paris Calcaire Grossier
3 megalospheric specimens.

33 *Nummulites striata* D'Orb Menton. This species is judged to be close to *N distans* and is referred to the third lineage of Arn Davies.

Explanation of Tabulated Data

The characters of taxonomic importance have been tabulated for certain species. Microspheric and megalospheric generations have been considered separately. The characters of primary importance for the recognition of the species group are the arrangement and appearance of pustules, the pattern of the septal filaments and the chamber shape and appearance of the septa.

In the tabulation of microspheric generations the manner of description is as follows.

1. Dimensions of the test.
   - D the mean diameter in millimetres of available adult specimens of the species.
   - T the mean thickness of these individuals.
   - N. the approximate number of whorls corresponding to a test of diameter D_m = mean diameter.
2. Spire Pace
   In this tabulation the rate of expansion of the spire is illustrated by the radii (R) in mms of ~~successive~~ stated whorls of the test W 2, 4, 6, 8, 10, 12, 16.
3. Chamber Counts.
   The number of septa per whorl is given in the form of a count for the ~~[illegible]~~ complete whorl.

The working sheets of graph paper illustrate the ~~distribution and~~ variability in number of septa in successive whorls of the microspheric specimens examined.

Sample 8, a single microspheric individual from Gosport is labelled N. laevigata. A comparison of the spire face and number of septa of this specimen with that of N planulatus & N laevigata reveals that it approaches the condition described for Nummulites aquitanicus. The axial section and the decorticated surface of the specimen reveal numerous small pustules pillars disposed along the trace of the septal filaments. These do not anastomose with adjacent filaments in the manner which gives rise to the sub reticulate pattern in N. laevigatus and so with respect to this character also this species is distinct from both N. planulatus & N laevigatus. It is considered to represent Nummulites aquitanicus

N. perforatus — N aturicus

Schaub 1951 states that N. perforatus in the sense of Boussac (1911) probably comprises the park of ~~many~~ several evolutionary series. It seems useful then, to distinguish here, two species for the apparently distinct groups samples 11, 12, 13 ~~[illegible]~~ from SW France and 14,15,16, 17 from the vicinity of Genoa.

The microspheric specimens appear to be distinguished by a difference in thickness of the overall test and a slight distinction in chamber shape and its variation during ontogeny.

The megalospheric generations are differentiated on the character of the megalosphere and also the dimensions of the test and structure as seen in axial sections.

It is suggested that the samples 11, 12, 13 represent N. aturicus described from Fontaine de la Medaille and 14, 15, 16, 17 belong to the species N. perforatus.

The specimens of the sample from Kressenberg, 20, show meandrine filaments with numerous large granules situated on the septal filaments, the structure developed in certain species of the group of _Nummulites burdigalensis_ of Schaub (1951).

The second table lists the characters of the megalospheric generations.

The size and form of the two embryonic chambers is a useful character of the megalospheric individuals for the revealing the affinities of the species.

The chamber form and the shape of the septa is best illustrated by diagrams, the key to which are given in the column headed "Chamber shape and shape of septa."

The nucleoconch and the first chamber of the second whorl of a selected specimen of each species are illustrated.

The regularity of growth and other characters of the spire are illustrated by diagrams for which the key is given in column 5.

The thickness of the marginal cord is also best illustrated by these diagrams and as the value of $P = \frac{\text{thickness M.C.}}{\text{chamber height}}$, is of relatively little use for these forms, it is not given in the tabulation.

Comments on Megalospheric forms.

Samples 18 and 19 are labelled _Nummulites globularia_ Cuiz However the filaments of all specimens show a tendency towards meandrine ~~form~~ pattern. So also the thickness of the test is not sufficiently great for this species. It has been referred tentatively to the second lineage of Davies and it is considered close to _Nummulites planulatus._ It is appreciated that the filaments of some subspecies of _N. globulus_ show variations from the strictly radial form. (Schaub p105 - 107)

The megalospheric forms here described as Nummulites planulatus, N laevigatus and N brongniarti, are clearly the alternating generations of the associated microspheric forms. This also applies for the micro & megalospheric specimens grouped as N aturicus and N perforatus. *

These two species show a relatively clear difference in the structure of the nucleoconch. Thus N. aturicus has a smaller protoconch and a clearly defined hemispherical to sub-globular deutroconch, whereas N perforatus has a large and irregular protoconch and apparently none of the 7 equatorial and 5 axial sections show a differentiated deuteroconch. The chamber counts of the two species show some difference and so also, as in the microspheric generations, there are differences in the dimensions of the test. Thus the axial sections are quite characteristic, N perforatus being clearly thicker than N. aturicus

FIGS 29 - 32 are drawings of N. aturicus
FIGS 33-35 are specimens of N. perforatus for comparison.

FIGS 36, 37, 38 are photographs of equatorial sections of the forms, respectively Nummulites aturicus, N, perforatus and Nummulites sp from Gizeh.

The megalospheric specimens referred to Nummulites striata from the Calcaire Grossier, Paris have an even lenticular test, and thin peripheral margins. The regular, tight spire and chamber shape support the identification as N. striata. The simple radial septa and absence of clear pillars place the species in the first lineage of Davies.

Nummulites aff burdigalensis. Although their is a great difference in size, these specimens resemble the microspheric forms in the sample classified under the same specific name.

Sample 33, described as _Nummulites striata_ from NW Italy appears to be referable to the third lineage of Davies, since it is non granulate with meandrine septal filaments and very oblique septa. The regular coiling and little increase in height of successive whorls suggest strong affinities to the species _Nummulites distans_ Deshayes 1838.

References.

Barker R N 1939 Species of fam. Camerinidae in Tertiary & Cret. of Mexico Proc US Nat Mus 86 No 3057 p 305

1938 Nomenclature Camerina petri and Nummulites striatoreticulatus Geol Mag Vol 75 pp 49-51 p III

Bieda 1959 Nummulites of the Magura Series Polish W. Carpathians Instytut Geologiczny Bulletin No 131

Carpenter 1862 Introduction to the study of Foraminifera. London

Cole W. S. 1953b Criteria for recognition of certain assumed Camerinid genera Bull Amer. Pal. ~~28~~ (1954) V35 No147 p29-46

1957 Larger Forams from Eniwetok Atoll Geol Surv. Prof Paper 260-V

1958a Names & variation in Certain American larger Foraminifera particularly the Camerinids Bull Amer Paleont. V38 No 173 p261

1959 Names and variation in certain Indo-Pacific Camerinids Bull Amer Pal. V39 No181

D'Archiac & Haime 1853-5 Description des Animaux fossiles du groupe nummulitique de l'Inde, Paris.

Davies A M 1935 Tertiary Faunas Murby., London

Davies L M 1927 The Ranikot Beds of Thal. Quart Jour. Geol Soc Lond 83 266

Frizzel 1945 Dimensions, whorls and Chamber Counts in Camerinidae Jour Pal Vol 19 p 75

Gill W D 1953 Facies & Fauna in the Bhadrar beds of the Punjab Salt Range Pakistan. Jour Pal Vol 27 no 6 pp 824

Glaessner 1945 Principles of Micropalaeontology Melb Univ Press Melb.

Grimsdale & Smout 1949 Note of the aperture of Nummulites Lamarck Quart Jour Geol Soc Lond. 104, p 324-6

Hofker. J Foraminifera of the Siboga Expedition

Hofker J 1956 Tertiary Foraminifera of coastal Ecuador
Part II additional notes on the Eocene species
Jour Pal Vol 30 no 4 p 891-958

Nagappa Y 1959 Micropalaeontology

Ovey 1935
~~Abattat~~ 1926. ~~The zonal di~~
Puri H. S 1957 Jour. Palaeontological Society of India.

Reiss 1958 Classification of Lamellar Foraminifera
Micropalaeontology 4(1): 51-70
Reiss and Merling. 1958 Structure of some Rotaliidea
Geol Surv. of Israel
Paleont. Div. Jerusalem
Rozlozsnik 1929 "~~Studien über Nummulitesen Assilinen~~"

Schaub. 1951 Stratigraphie und Palaeontologie des Schlierenflysches.
Schweizer Pal. Abh., vol. 68, 1951
Smout 1954 Lower Tertiary Foraminifera of the Qatar
Peninsula London British Mus. (Nat Hist) 70
Wrigley and Davis AG. 1937 Occur. Nummulites planulatus in England
Wd
Proceedings Geologists Assoc^n Vol XLVIII Part 2

MEGALOSPHERIC GENERATION	SPECIMENS	Chamber shape and shape of septa	Dimensions of the Nucleoconch.		Character of the Spiral See FIG	Distribution of Granules.	Number of septa in whorl						Dimensions Test			Nature o
			a, diam protoconch mm	distance across nucleoconch			1	2	3	4	6	7	Diam	Thick	equivalent number of whorls	
N. aff planulatus	18, 18A, 19A	FIG 12	0·32	0·60	17	absent	10	20	30	38			3·6	1·1	4	Radial + mea
N. planulatus	1E 2D-F 4B 5A	FIG 13	0·31	0·55	18	absent	10	20	25	30			4·0	1·35	4	meand
N. laevigatus	5, 5A	FIG 13	0·30	0·65	19	Occur on and elongated along the filaments.	11	20	30	33			4·4	1·3	4	sub retic
N. brongniarti	10 10D 10G	FIG 13	0·55	0·86	20	Fine and very numerous	5	10	15	19	19	19	5·0	1·4	7	comple ob.
N. aturicus	13A-D 11A-D	FIG 36	0·8	1·1	21	Fine and comparatively rare, situated between filaments	7	11	18	26	35		7·7	2·6	6	fine m
N. perforatus	16B, 17D,E,F	FIG 37	1·2?	1·2?	22	Similar. Small pustules between filaments.	5	10	16	20	21		6·0	3·5	5	Parallel probably
29A from Gizeh	29A, B	FIG 14	0·66	·80	23	Small rare pustules along the septal filaments. Irregular	6	15	23	28	31		6·0	1·7	5	meand
N variolarius	23, 24, 25	FIG 14	0·08	0·11	24	Small polar pustule present in some specimens. May also be absent	8	14	19	24			1·2	0·6	3	radial
N cf. striata	32A	FIG 14	single specimen 0·62? division indistinct	0·75?	25	Small pillars at the poles, pustules absent	14	23	29	32	35	37	4·5	2·1	5	Radial s to anast poles
N aff. burdigalensis	20 B, C	FIG 15	0·15	0·30	26	pillars present on septal filaments	7	15	21				2·7	1·0	4	Simple b of patte
N aff. distans	33c	FIG 16	single specimen 0·80? division indistinct	1·15	27	lacks pillars	10	18	27	39			8·0	2·5-3·0	4	sigmoida mean

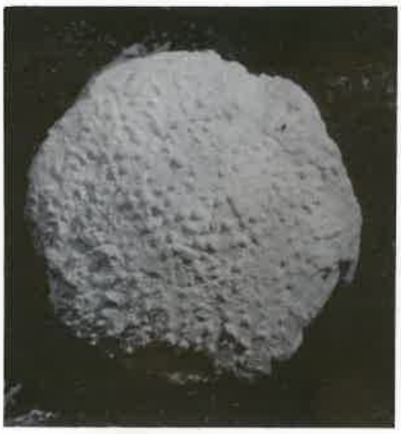
…RIC …ON	SPECIMENS	Chamber shape and shape of septa	Dimensions of the Nucleoconch. d, diam protoconch mm	Dimensions of the Nucleoconch. distance across nucleoconch	Character of the Spiral See FIG	Distribution of Granules.	Number of septa in whorl 1	2	3	4	6	7	Dimensions Test Diam	Thick	equivalent Number of whorls	Nature of Septal Filaments
…ulatus	18, 18A, 19A	FIG 12	0.32	0.60	17	absent	10	20	30	38			3.6	1.1	4	Radial tending to meandrine
…us	1E 2D-F 4B 5A	FIG 13	0.31	0.55	18	absent	10	20	25	30			4.0	1.35	4	meandrine
…atus	5, 5A	FIG 13	0.30	0.65	19	Occur on and elongated along the filaments.	11	20	30	33			4.4	1.3	4	sub reticulate
…iarti	10 10D 10G	FIG 13	0.55	0.86	20	Fine and very numerous	5	10	15	19	19	19	5.0	1.4	7	complex not observed.
…us	13A-D 11A-D	FIG 36	0.8	1.1	21	Fine and comparatively rare, situated between filaments	7	11	18	26	35		7.7	2.6	6	fine meandrine
…atus	16B, 17D,E,F	FIG 37	1.2?	1.2?	22	Similar. Small pustules between filaments.	5	10	16	20	21		6.0	3.5	5	Parallel but incomplete probably also meandrine
…izeh	29A, B	FIG 14	0.66	.80	23	Small rare pustules along the septal filaments. Irregular	6	15	23	28	31		6.0	1.7	5	meandrine
…arius	23, 24, 25	FIG 14	0.08	0.11	24	Small polar pustule present in some specimens. May also be absent	8	14	19	24			1.2	0.6	3	radial simple
…ata	32A	FIG 14	single specimen 0.62? division indistinct	0.75?	25	Small pillars at the poles, pustules absent	14	23	29	32	35	37	4.5	2.1	5	Radial some tending to anastomose near Poles
…digalensis	20 B, C	FIG 15	0.15	0.30	26	pillars present on septal filaments	7	15	21				2.7	1.0	4	Simple but detail of pattern obscure
…stans	33c	FIG 16	single specimen 0.80? division indistinct	1.15	27	lacks pillars	10	18	27	39			8.0	2.5-3.0	4	sigmoidal and meandrine

MICROSPHERIC GENERATIONS	Reference		Shape of Test	Dimensions			Character of spiral and regularity of growth	Radius (mm) of whorls					Septal Count - the number of septa in whorls									Marg… P = …
	Specimens	Figures		Diameter mms	Thickness mms	No. of whorls		4	6	8	12	16	2	4	6	8	10	12				
N. planulatus	1-4	FIG 4	planulate	8·2	1·3	8-9	Irregular, rel. few whorls initially tight, 8+later whorls expand rapidly	0·8	2·2	4·1			16	24	37	54	65/9					Becom… thicker. change… growth
N. aquitanicus	8-9	FIG 5	lenticular flattened	10·0	3·1	12	Numerous whorls, initially tight, 5-7 whorl increase rapidly, later whorls even.	0·7	1·4	2·7	6·0		13	21	31	42	57					Becom… thicker… relative…
N. laevigatus	5-7	FIG 6	lenticular	10-14	3·5, 4·0	13-17	Tight, whorls numerous, height relatively constant.	0·6	1·2	1·8	3·3		13	18	23	28	35	43	-	47/16		Relat… in thic… later w…
N. brongniarti	10	FIG 7	planulate large	20·0	3·0-4·0	24	Very tight, whorls extremely numerous, height of adult whorls relatively constant	0·65	-	2·0	3·6	5·5	12	15	16	18	18	21	-	20/16	19/25	Poorly relative… P ½-⅓ in… out te…
N. aturicus	11, 12	FIG 11	lenticular, fluted	2·1	2·5-5·0	23	Mod. tight, irregular	0·6	-	2·4	4·3	7·0	16	22	-	26	-	33	50/14	58/16		Well … ively c… thickne… whorls. …
N. perforatus	12A, 14-17.	FIG none	lenticular, thick	21, 1·8	6-9	24, 23	Mod. tight, irregular	0·8	-	2·2	4·5	6·5	s -	19	25	26	28	31	40/14	53/16	75/19	As fo… relat… P, …
29B N. from Gizeh	29	FIG 8	lenticular	8·0	2·6	8-9	Very tight. Regular whorls slowly increasing in height.	0·5	1·2	2·0	4·0		14	25	38	54						Very … ion co… becom… thicke…
N. aff. burdigalensis	20	FIG 9a	lenticular	12·0	4·5	13-14	Relatively tight, variable, early whorls show gradual increase in height, later even.	1·0	1·9	2·9	5·1		13	22	32	42						Thin, change… ¼ in …
N. aff. intermedius	22	FIG 10	lenticular flattened	11·0	2·5	12	Relatively tight, whorls 1-5 expand rapidly, later whorls even height commonly irregular	0·8	1·7	2·6	5·0		12	18	23	28	30	30				Relat… propo… from ½ to ⅓ i…

Radius (mm) of whorls				Septal Count - the number of septa in whorls									Marginal Cord $P = \frac{\text{Thickness cord}}{\text{chamber height}}$	Chamber shape					Shape of septa	Nature of septal filaments	Arrangement of pillars
6	8	12	16	2	4	6	8	10	12					description	early whorls L/H	early whorls W/H	late whorls L/H	late whorls W/H			
2.2	4.1			16	24	37	54	65/9					Becoming progressively thicker. Proportion changes during growth from $\frac{1}{2}-\frac{1}{5}$	High short upright	1/3	1/1	1/4	1/3	Long radial, thin relatively straight recurved distally.	Tending to meandrine	absent
1.4	2.7	6.0		13	21	31	42	57					Becoming progressively thicker. Proportion relatively constant $\frac{1}{3}-\frac{1}{4}$	Moderately high, relatively short, upright	1/3	–	1/3	–	Radial & slightly convex	Meandrine to subreticulate	Relatively numer[ous] large, radially [a...] septal filaments
1.2	1.8	3.3		13	18	23	28	35	43	–	47/16		Relatively constant in thickness in the later whorls $P\ \frac{1}{2}-\frac{1}{2.5}$	Low short	1/1	1/1	1/1	1/1	Short convex, relatively oblique.	Sub reticulate, simple	Numerous large ~~filaments~~ granules along filaments
5 –	2.0	3.6	5.5	12	15	16	18	18	21	–	20/16	19/25	Poorly developed relatively constant $P\ \frac{1}{2}-\frac{1}{3}$ in thickness throughout test.	Low, very long	1.5/1	1/1	5/1	1/1	Long fine, irregular with long acute posterior angle	Subreticulate complex.	Relatively sma[ll] very numerous appear as small pu[...]
–	2.4	4.3	7.0	16	22	–	26	–	33	50/14	58/16		Well developed, relatively constant in thickness in the later whorls. $P, \frac{1}{2}$ tending to 1	Low increasing in length, moderately ~~short~~—long	1/1.2	–	2/1	–	Oblique relatively straight not convex. Slightly irregular	Irregularly meandrine.	Small relatively rare between fila[ments]
–	2.2	4.5	6.5	s –	19	25	26	28	31	40/14	53/16	75/19	As for above, relatively thick. $P, \frac{1}{1.5}$ approx.	Low increasing in length, chambers somewhat longer.	1.2/1	1/1	3/1	1/1	Remain relatively straight and oblique but posterior peripheral angle better developed in later whorls	Apparently not grouped? Not clearly seen.	Small relatively abundant? betw[een] filaments
1.2	2.0	4.0		14	25	38	54						Very Thick, proportion constant about $\frac{1}{1.5}$ becomes gradually thicker with growth	Very short and low constant.	1/1	1/1	1/1	1/1	Short straight, oblique	Radial / to meandrine	Apparently abse[nt]
1.9	2.9	5.1		13	22	32	42						Thin, proportion changes from $\frac{1}{2}$ to $\frac{1}{4}$ in later whorls	Rhombic	1.2/1	1/1	1.2/1	2/1	Straight to convex inclined obliquely	Meandrine Fig 9b	Relatively smal[l] on filaments in a[...] part of test.
1.7	2.6	5.0		12	18	23	28	30	30				Relatively thin proportion decreases from $\frac{1}{2}$ in early whorls to $\frac{1}{3}$ in later.	Figure 10	1/1	1/1.5	1.5/1	1/1	~~R~~ Slightly convex obliquely inclined	Reticulate	Comparatively large & numero[us]

1D

FIG 1 a



4.3
TYPE 6

External (Polar) view.
N. laevigatus microspheric

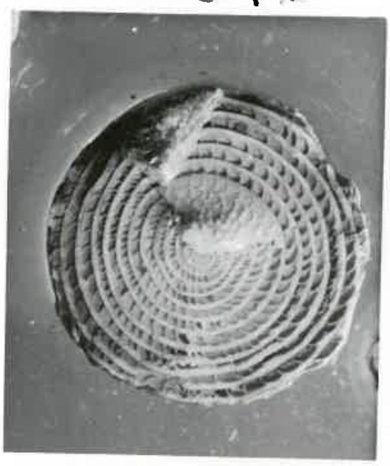
FIG 1 d

TYPE 6 4.4

Megalospheric N. laevigatus

All × 5

FIG 1 b



TYPE 6 a

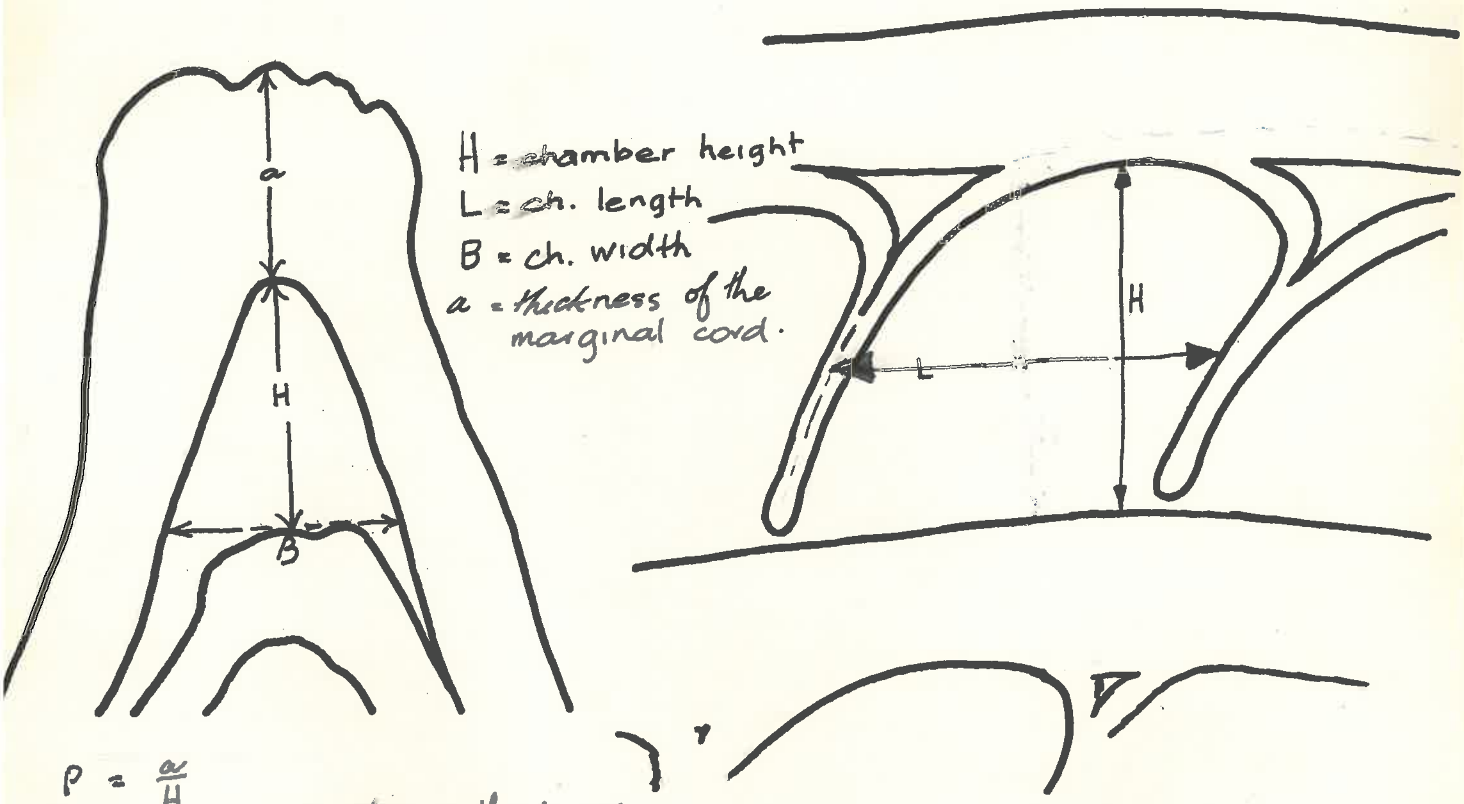
equatorial section
showing filaments
N. laevigatus microspheric

FIG 1 c

TYPE 6 4.2

Axial section
showing pillars
N. laevigatus microspheric

FIG 2



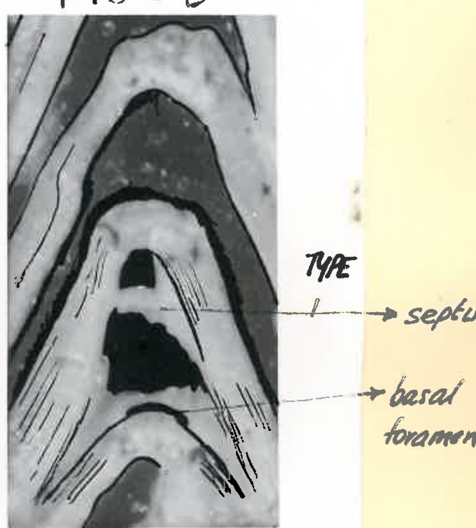
$P = \frac{a}{H}$

P the relative height or thickness of the marginal cord.

FIG 3A

TYPE 6 showing pillars in N. laevigatus

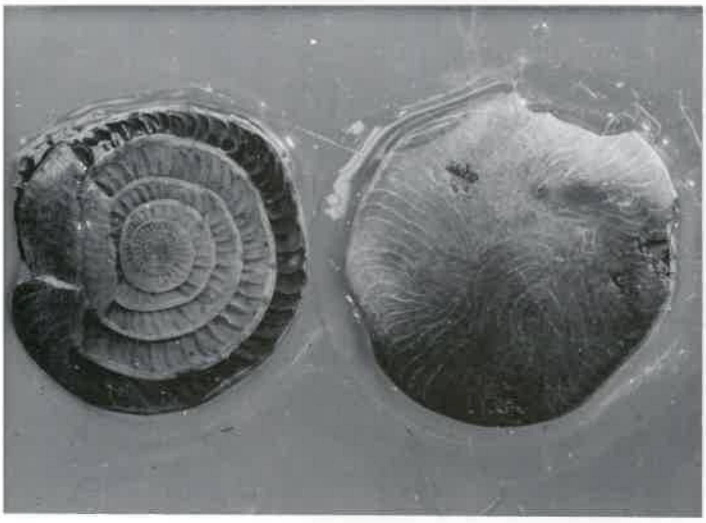
FIG 3B



septum + basal foramen, N. planula…

1 mm

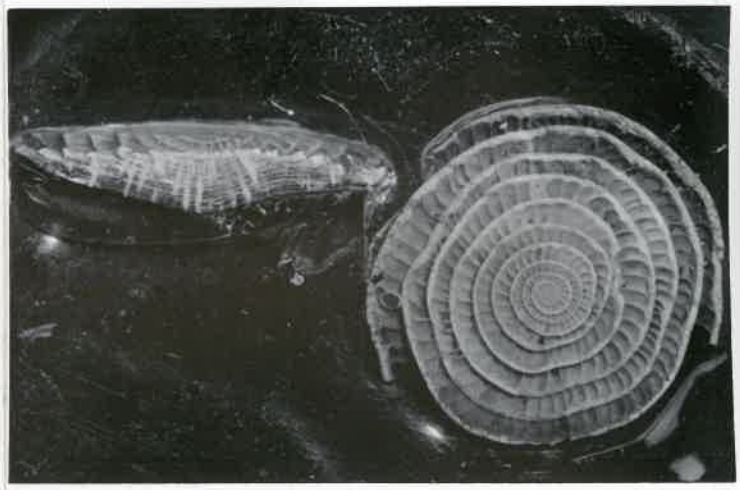
FIG 4



1 2 mm TYPE 4.1

N. planulatus

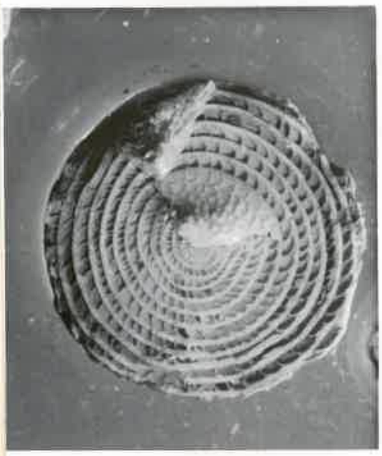
FIG 5



1 2 mm 8A 4.5

N. aquitanicus

FIG 6



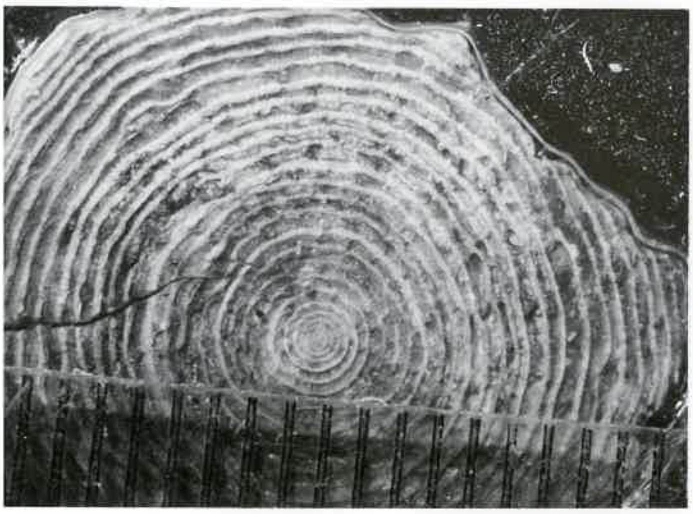
mm 1 2 a

TYPE 6

All × 5.

N. laevigatus

FIG 7



10E 4.17

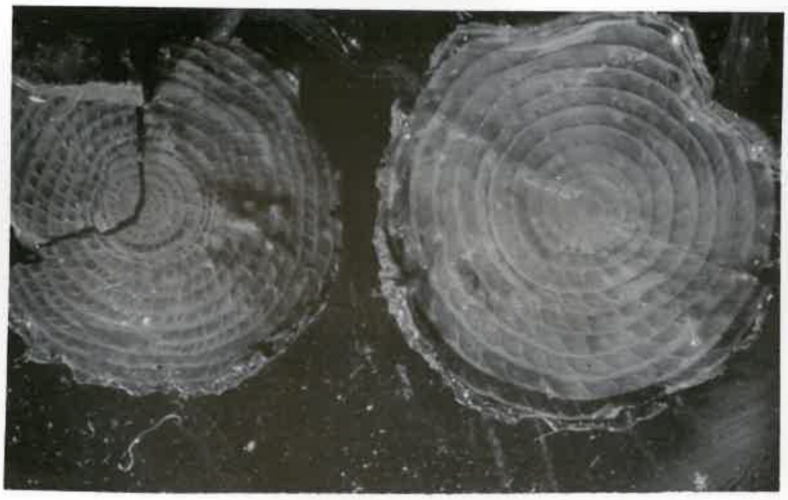
Nummulites brongniarti

FIG 8

29 ciiiii 4.14

N. (microspheric) from Gizeh

FIG 9a



20E i ii 4.8

×5

N. aff burdigalensis

FIG 9b

20A 4.10

×5

N. aff burdigalensis

FIG 10

22B 4.12

×5

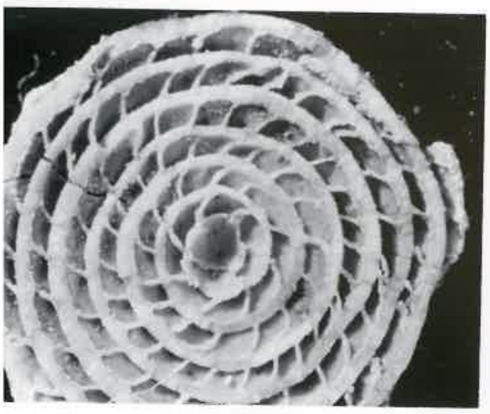
N. aff intermedius

FIG 11

12 Bii

N. atuvicus ×16

FIG 36 N atuvicus



11 D 3

9

×10

N. perforatus

FIG 37 17E 3.?

10

×10

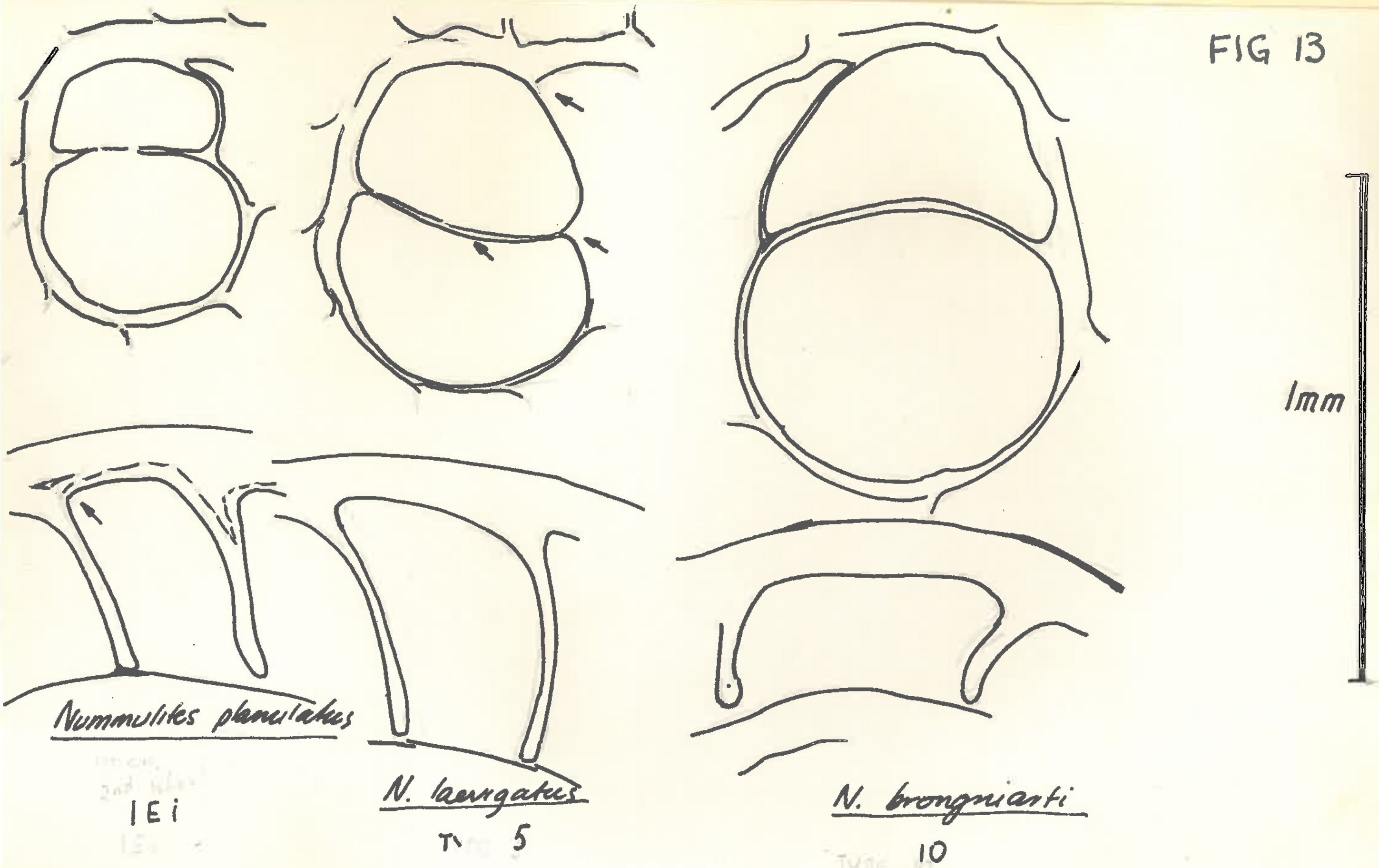
FIG 38. GIZEH

29A5

14

×10

FIG 13



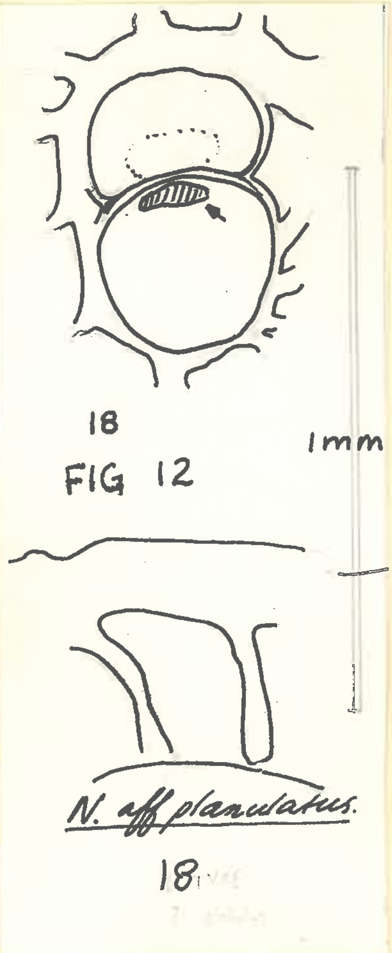


FIG 12

FIG 15

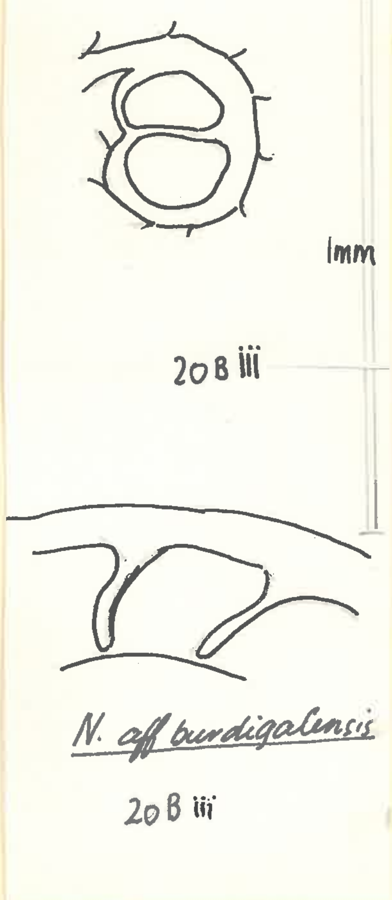
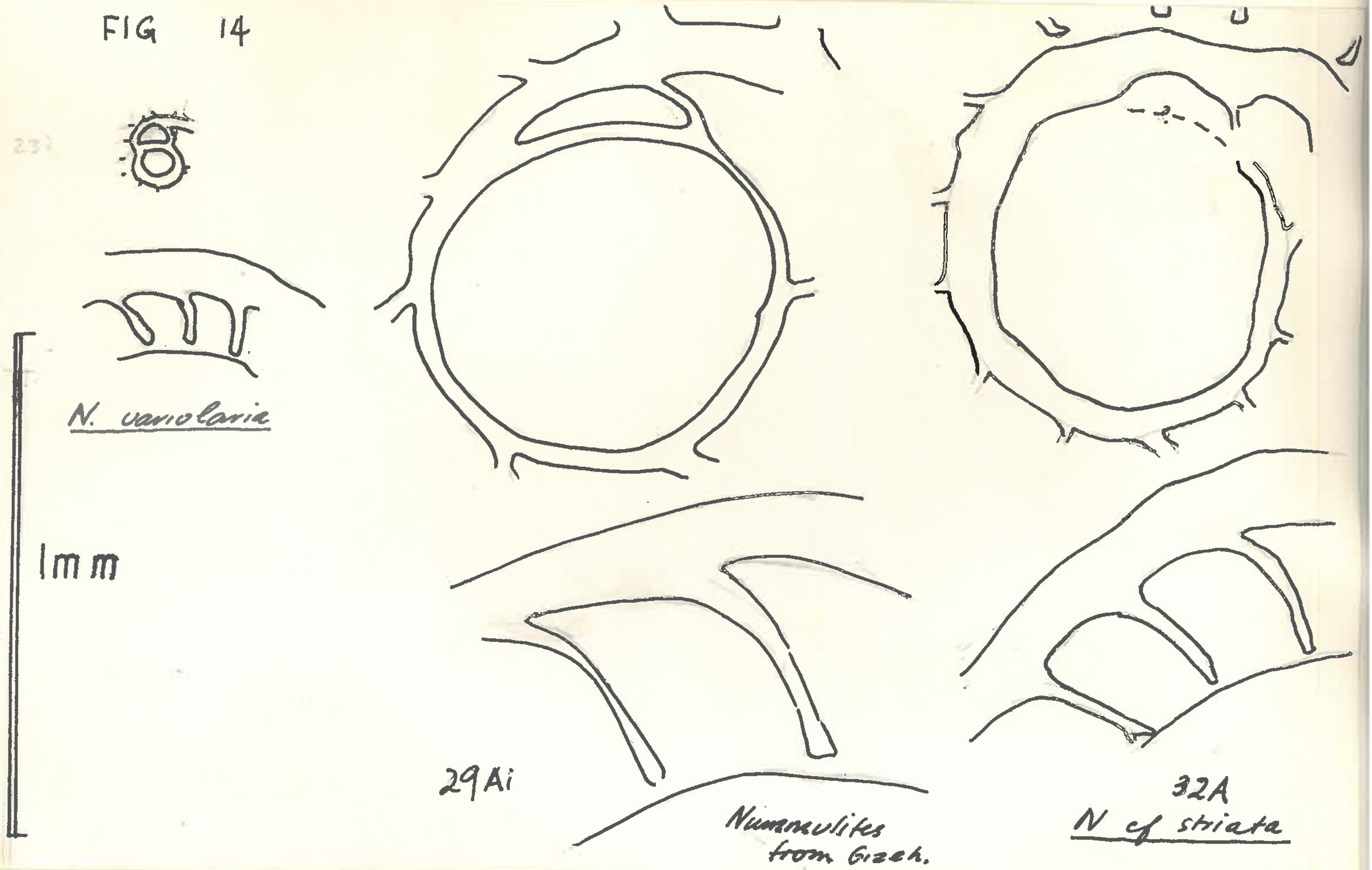
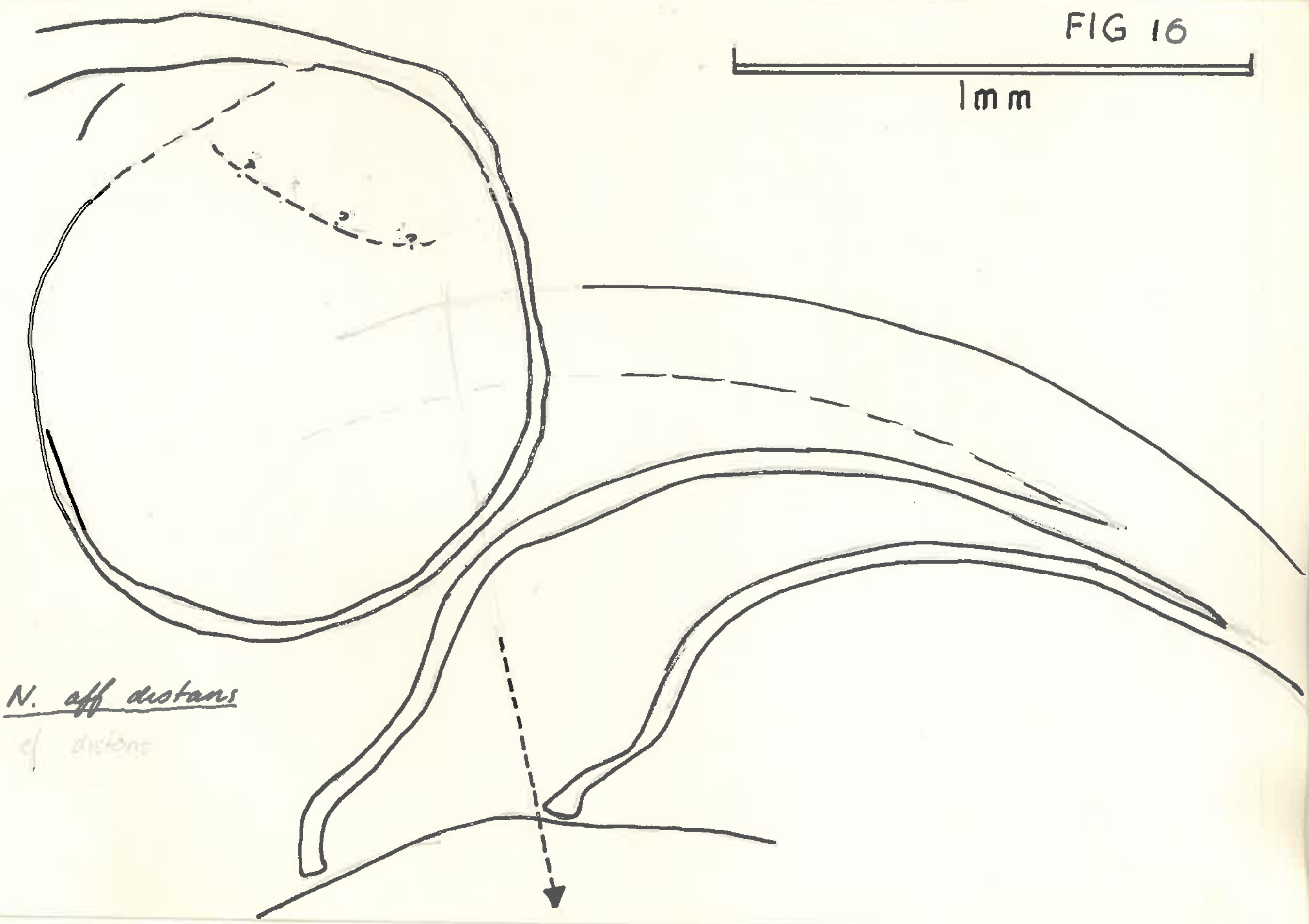


FIG 14



N. variolaria
1mm
29Ai
Nummulites from Gizeh.
32A
N cf striata

FIG 16



1mm
N. aff distans

FIG 17 (18)

? aff N. planulatus

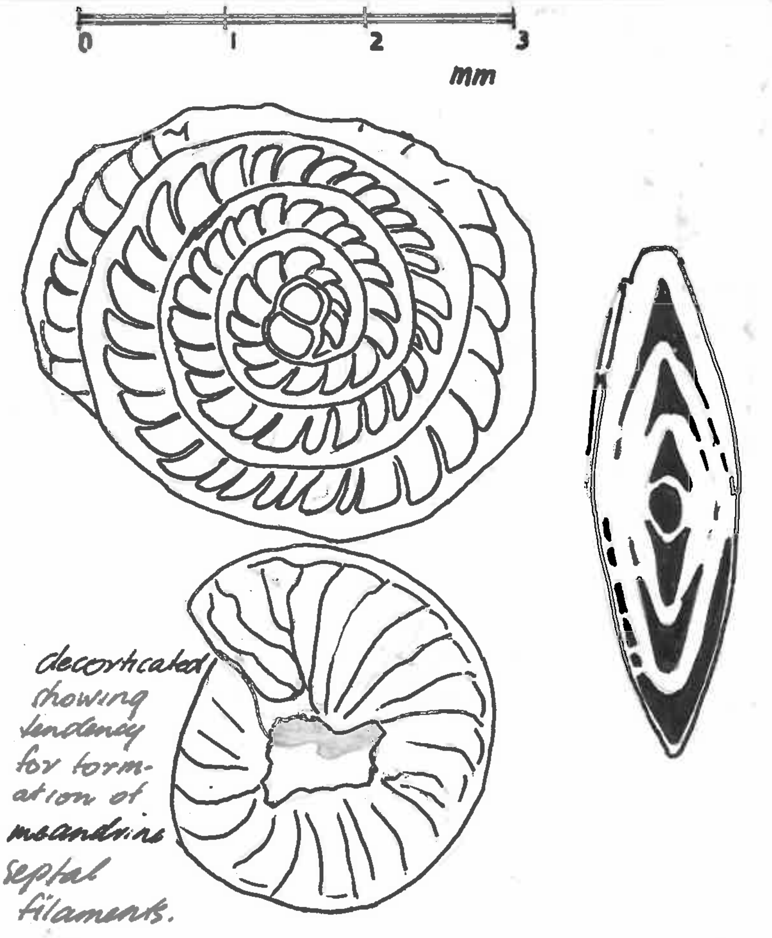


FIG 18 (2)

N planulatus

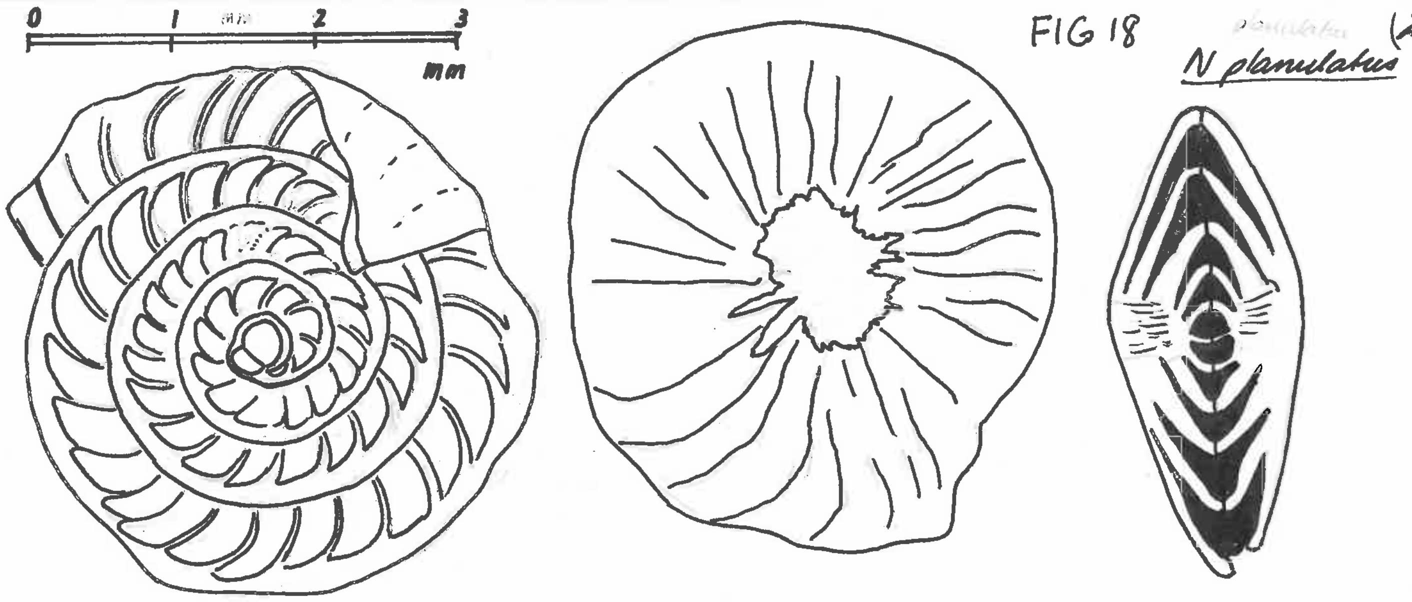


FIG 19

N. laevigatus

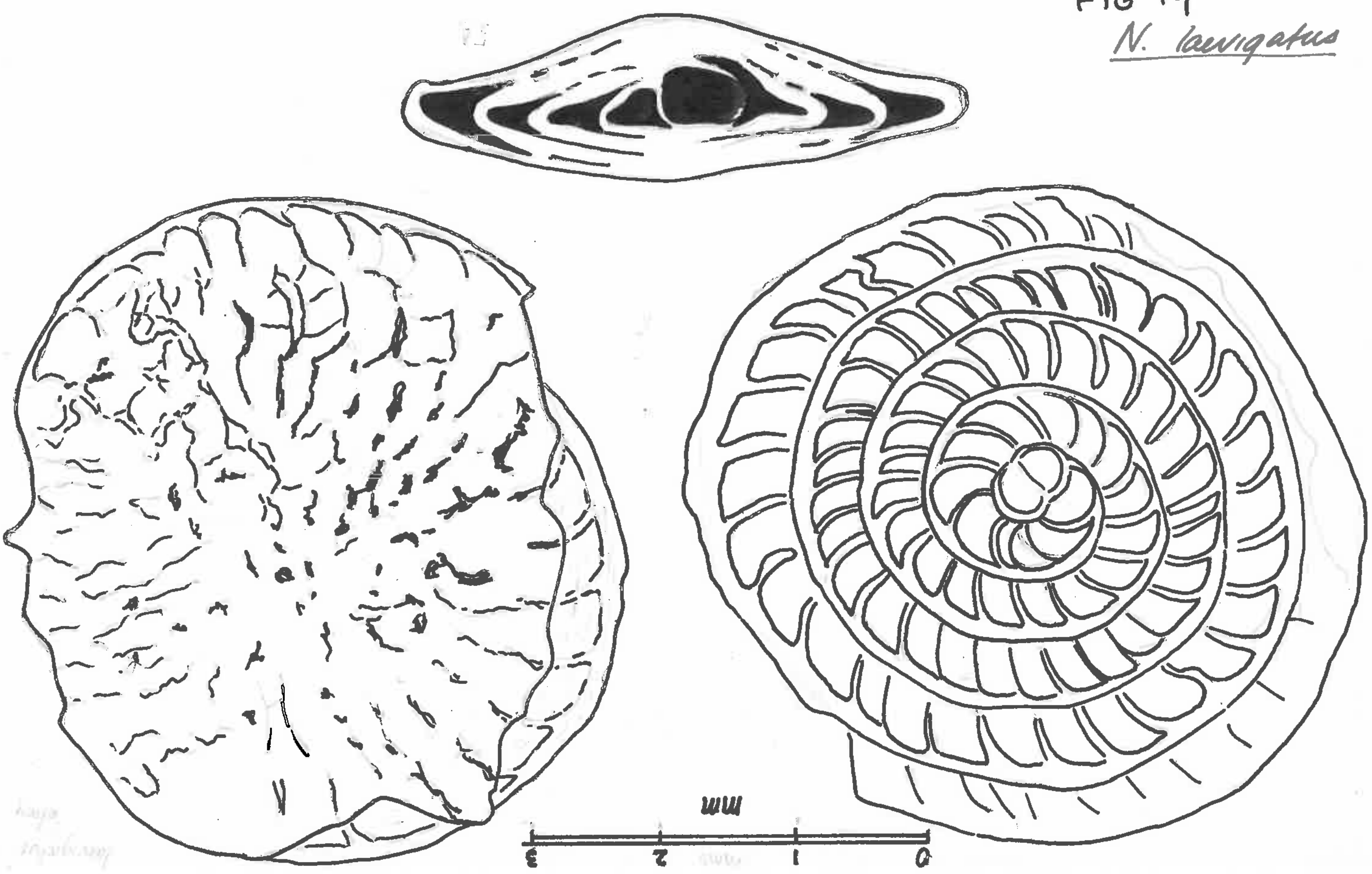


FIG 20 (10)

N brongniarti

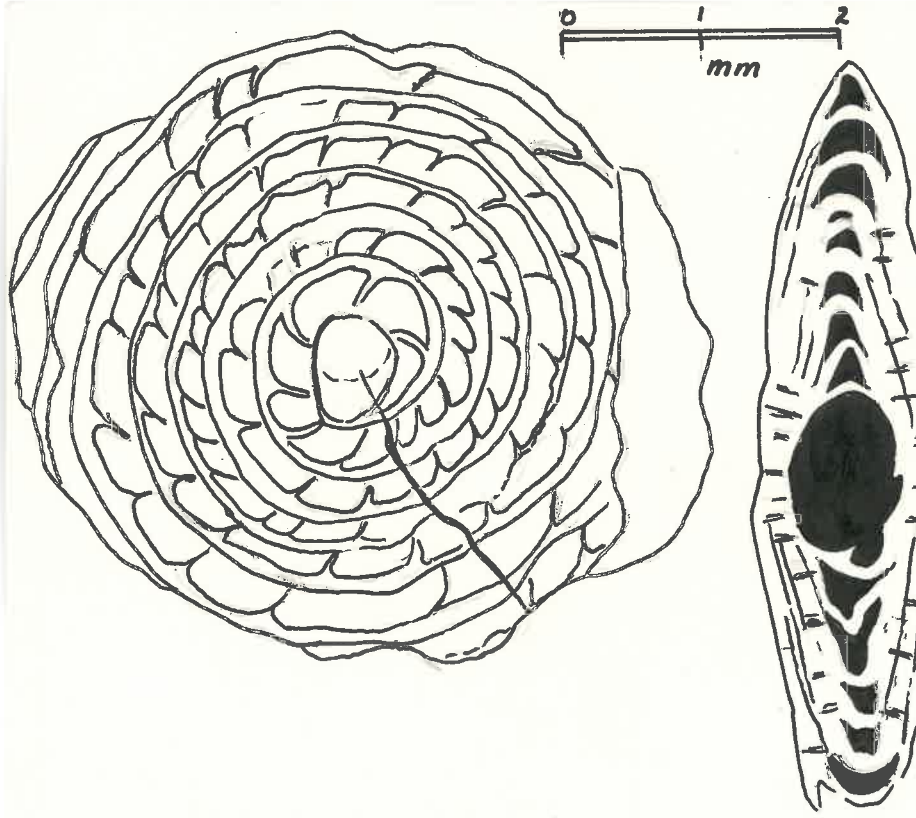


FIG 21

N. aturicus

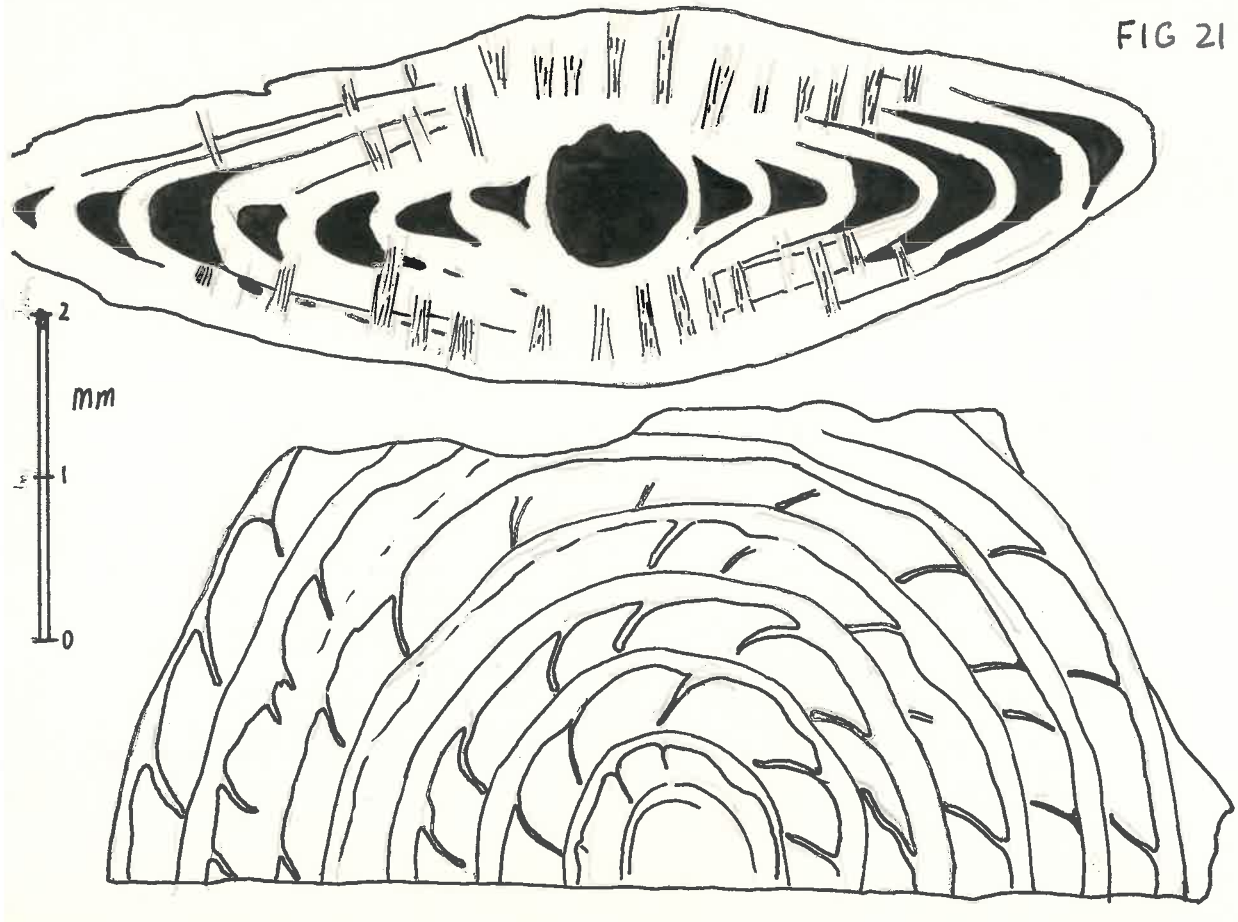
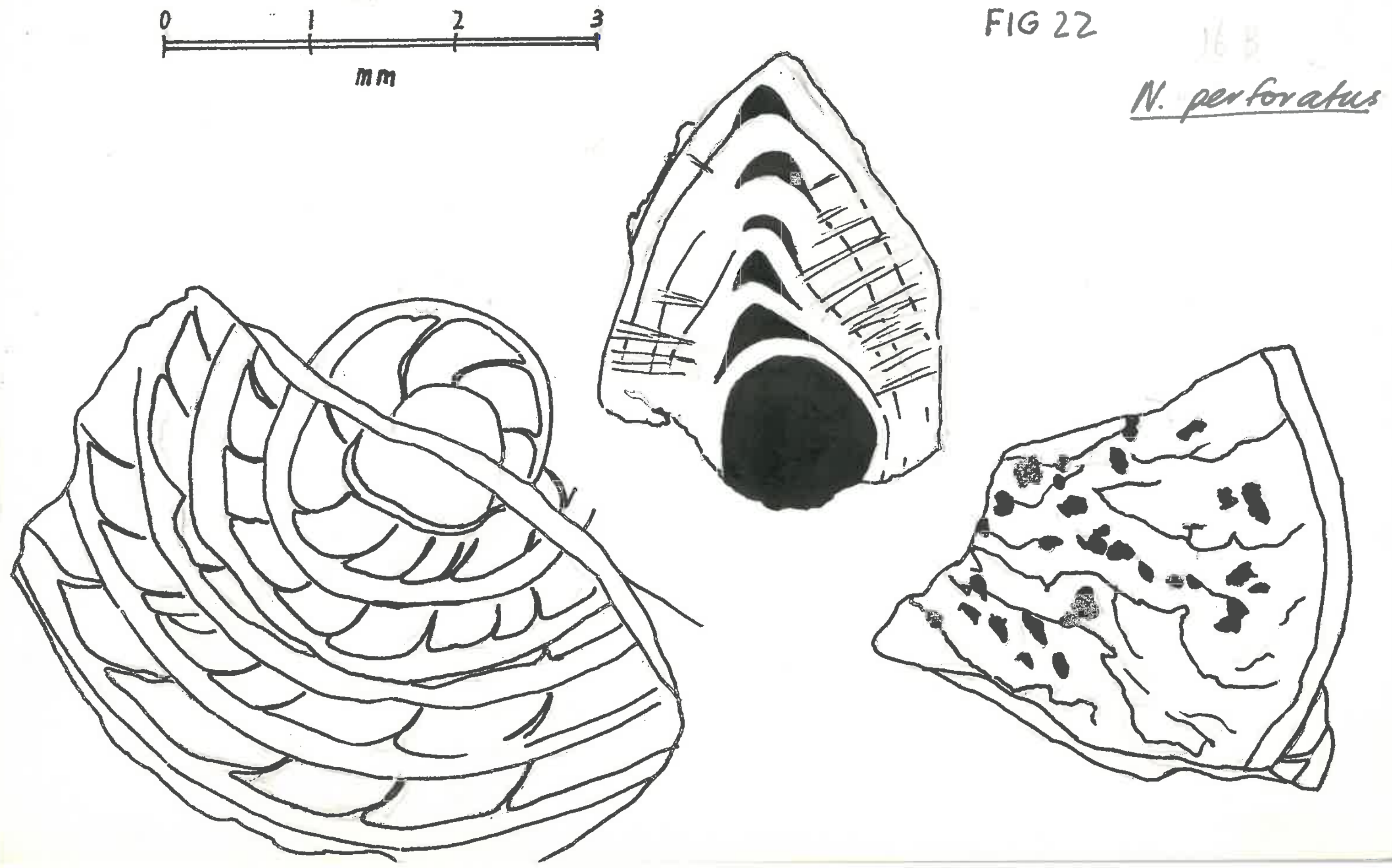


FIG 22 16 B

N. perforatus



29

FIG 23

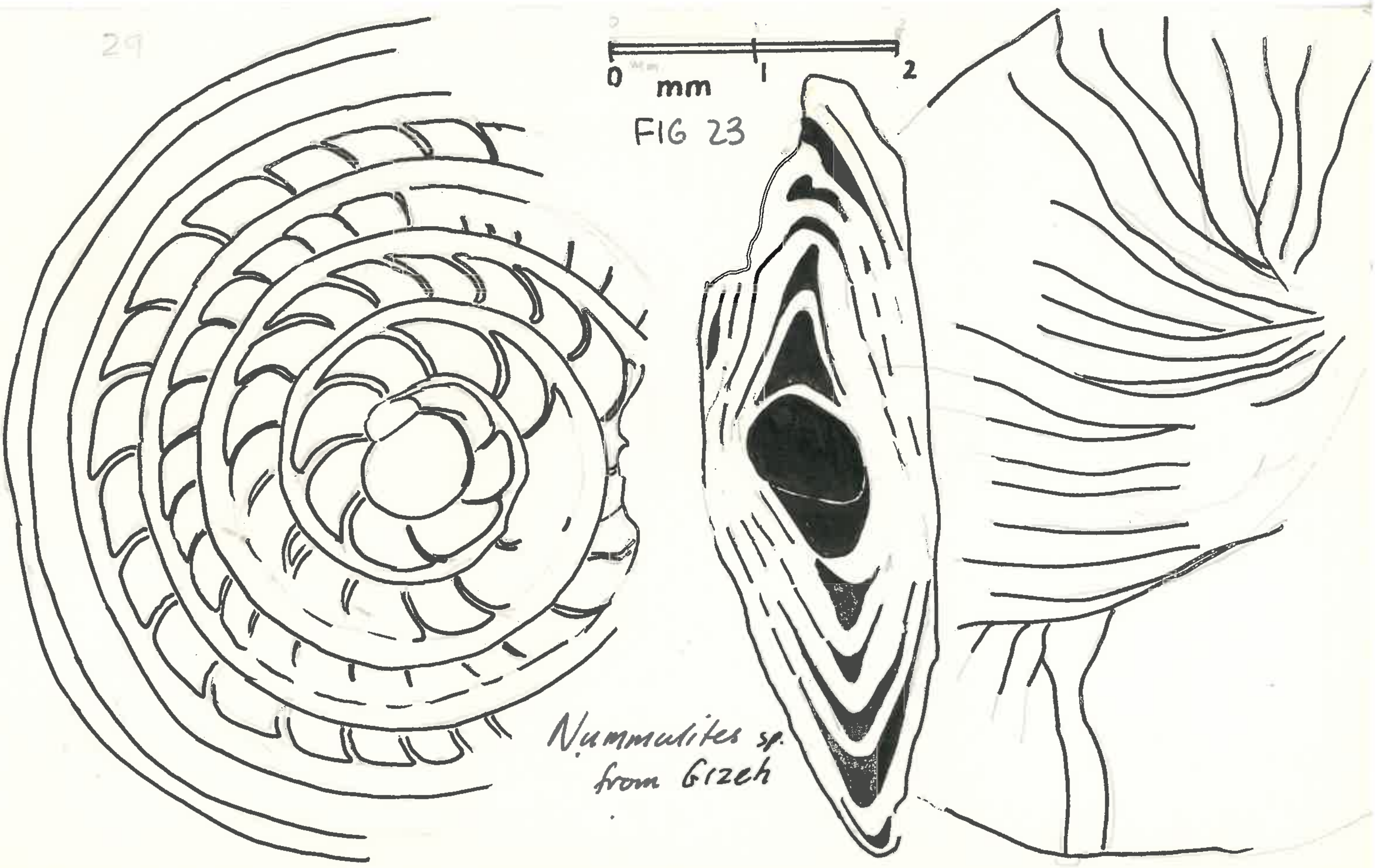
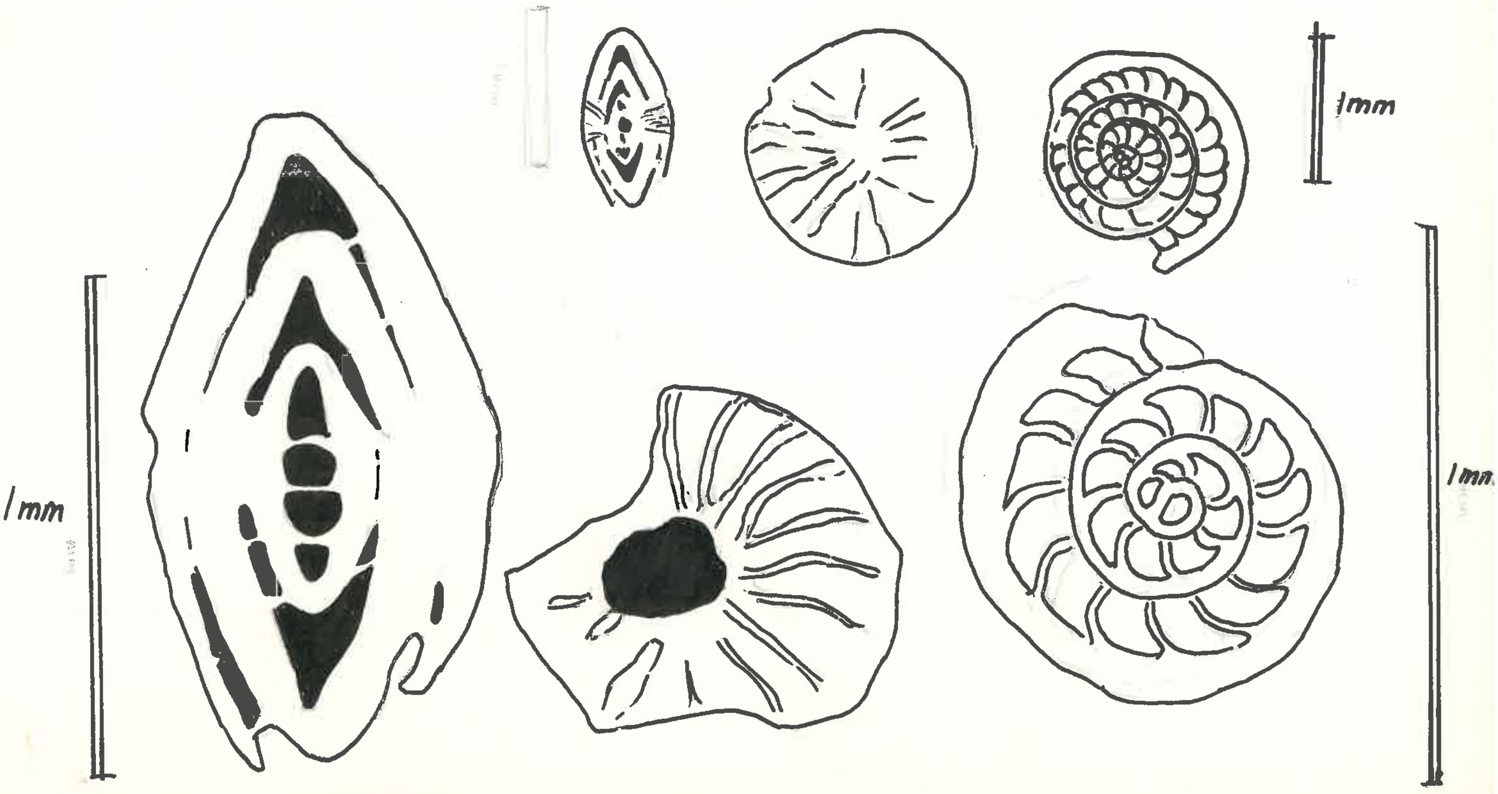


FIG 24

N. variolaria

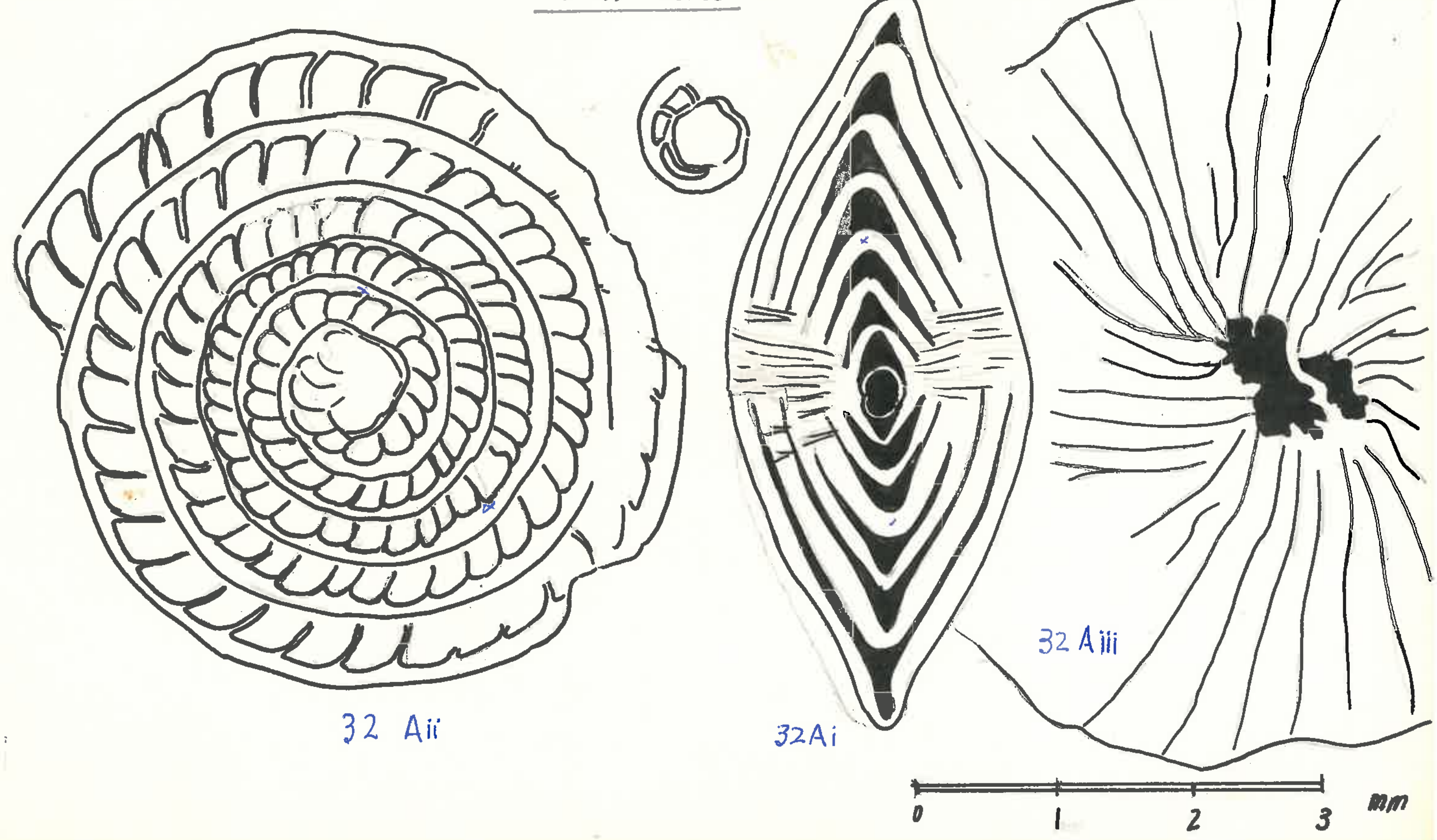
23



32

N. striata

FIG 25



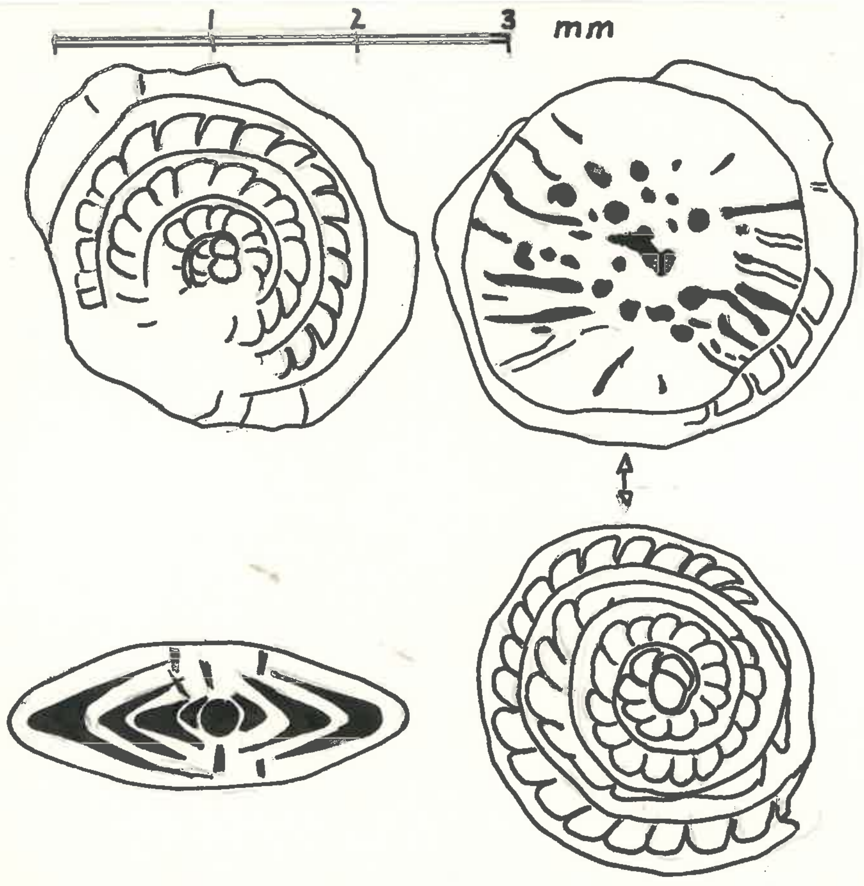


FIG 26

N. aff burdigalensis

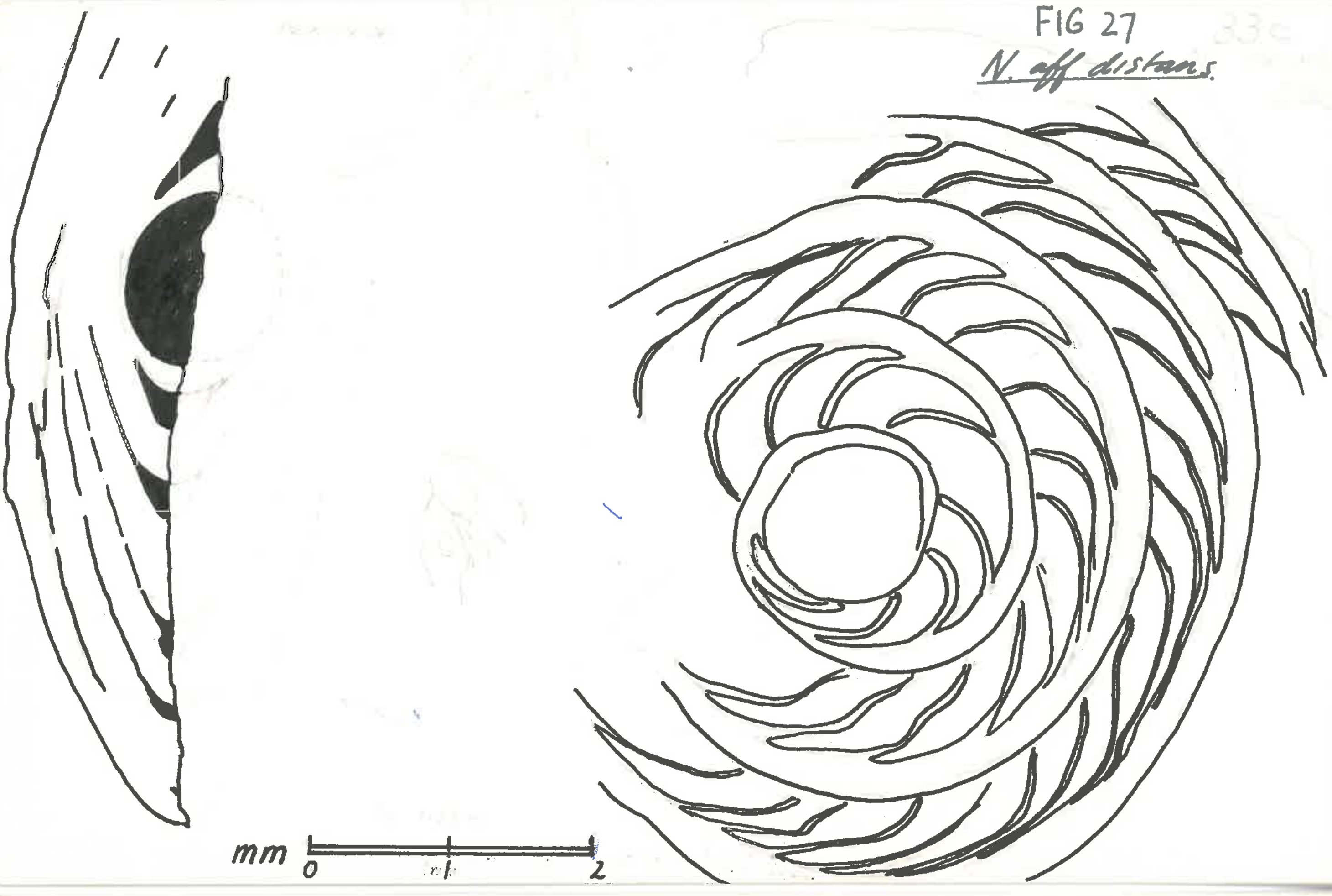


FIG 27

N. aff distans

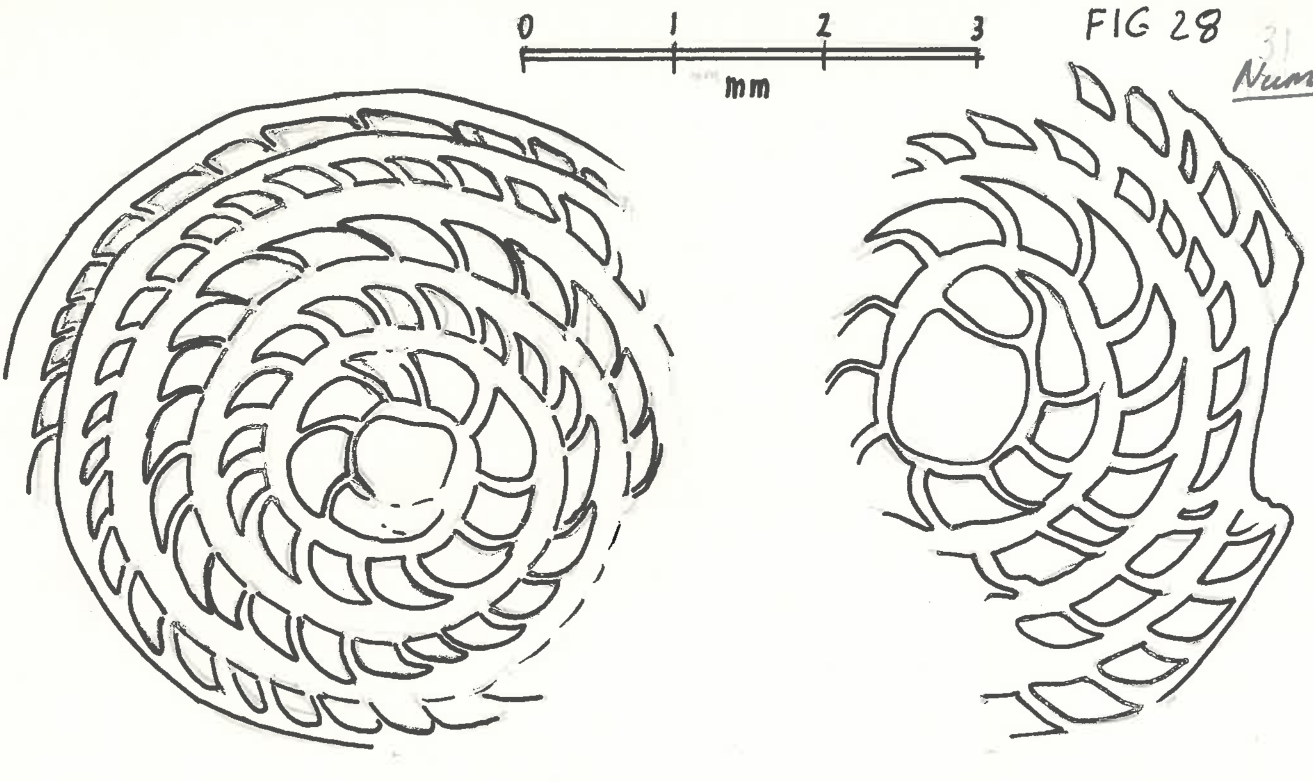


FIG 28

Nummulites sp

GIZEH

FIG 29

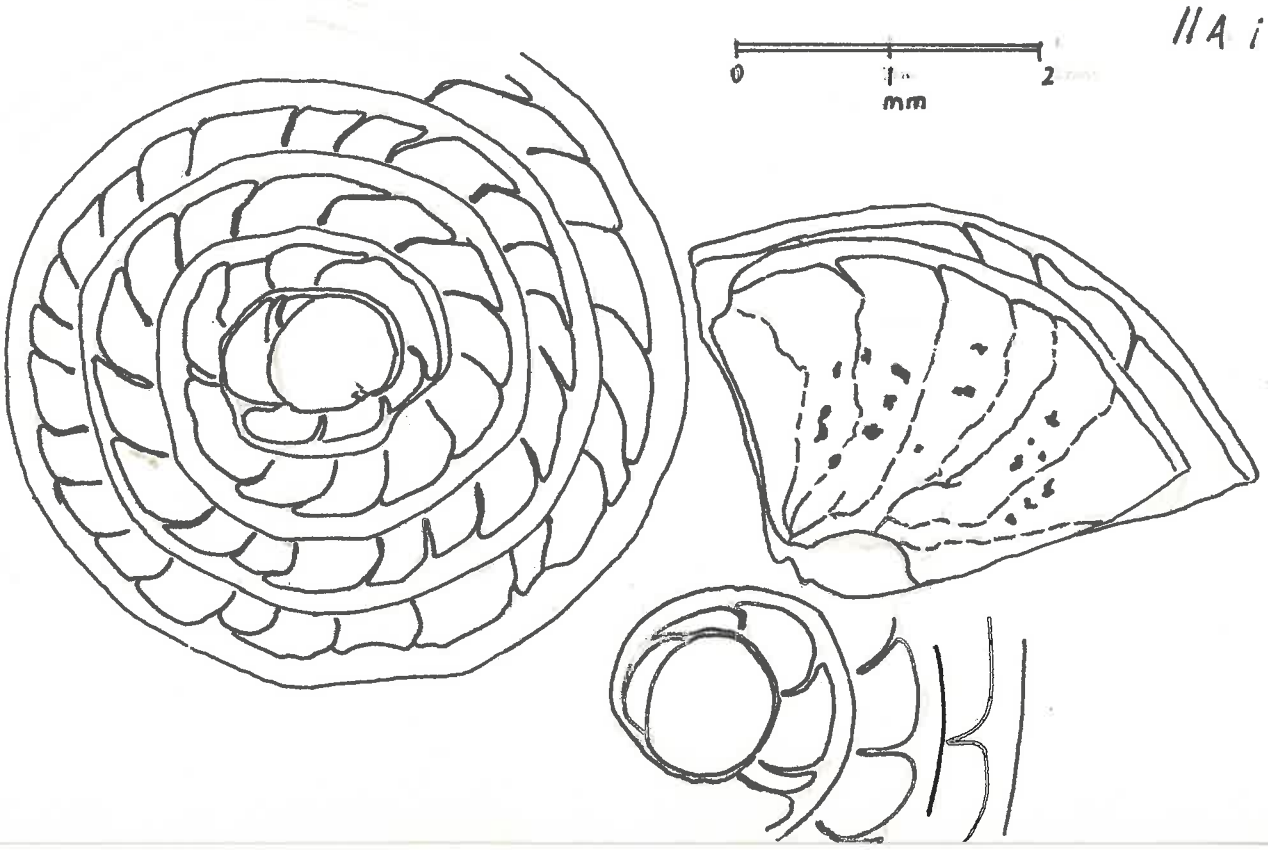
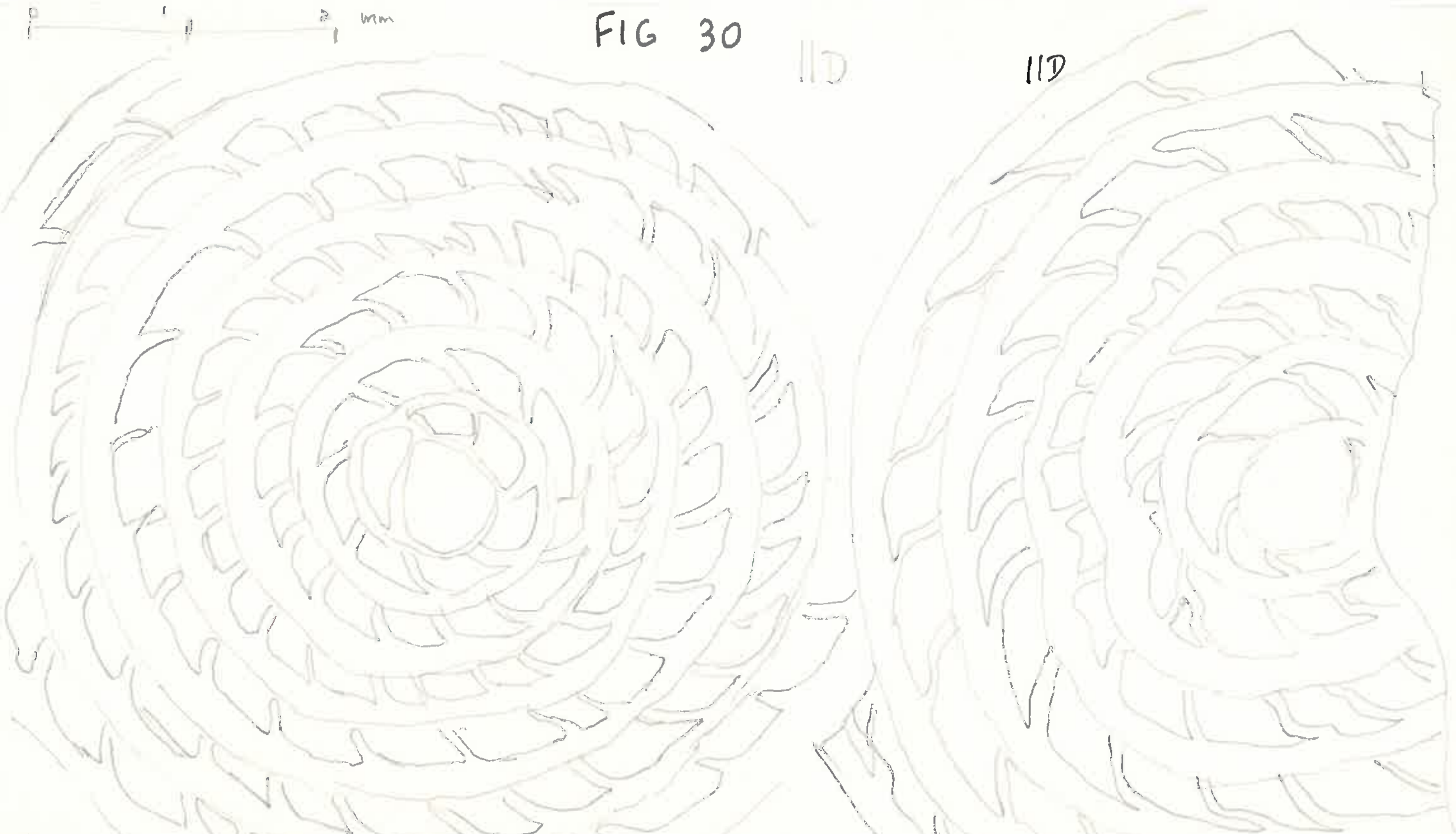


FIG 30



This specimen is now in the collection reserved for examination purposes.

FIG 31

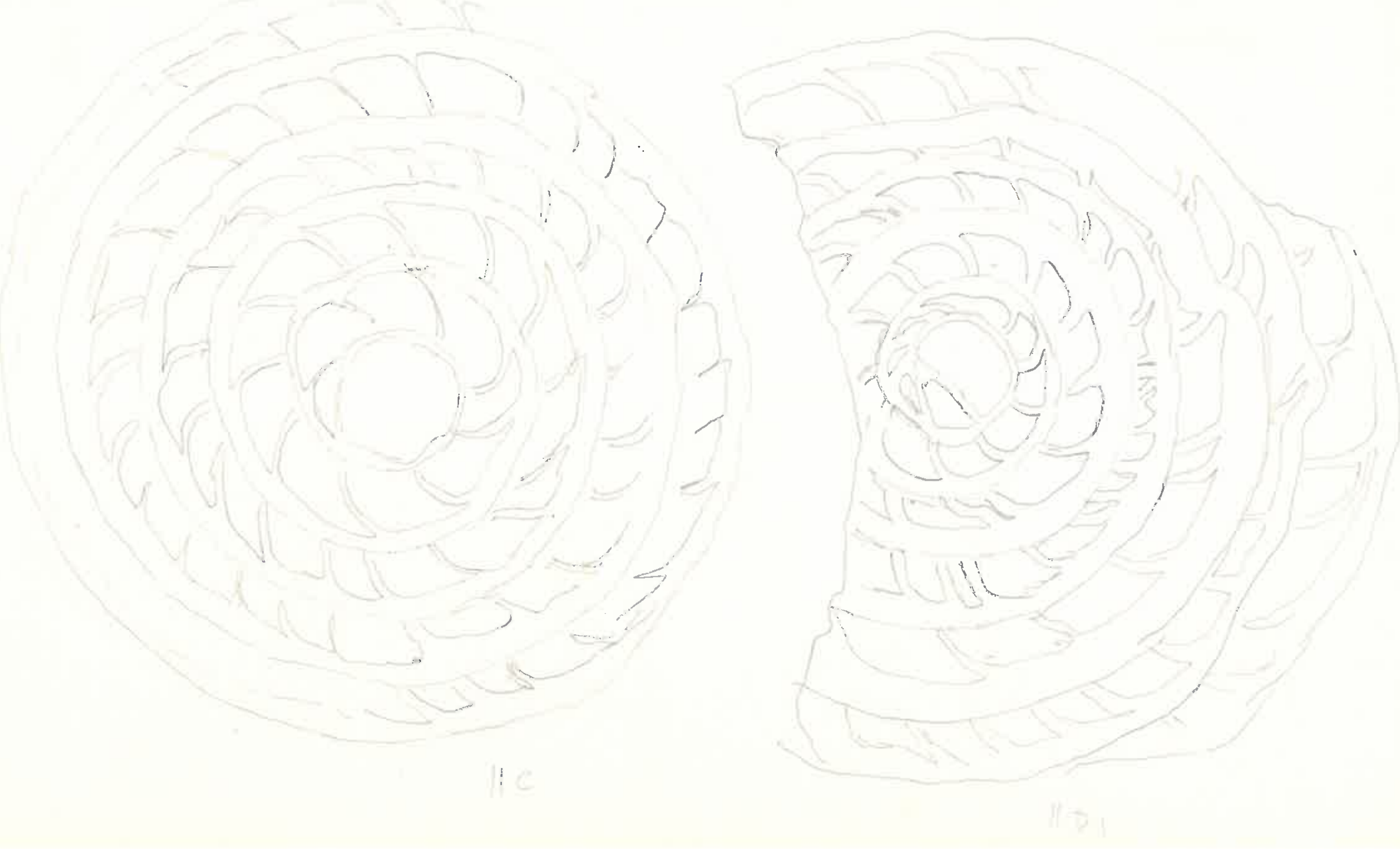


FIG 32

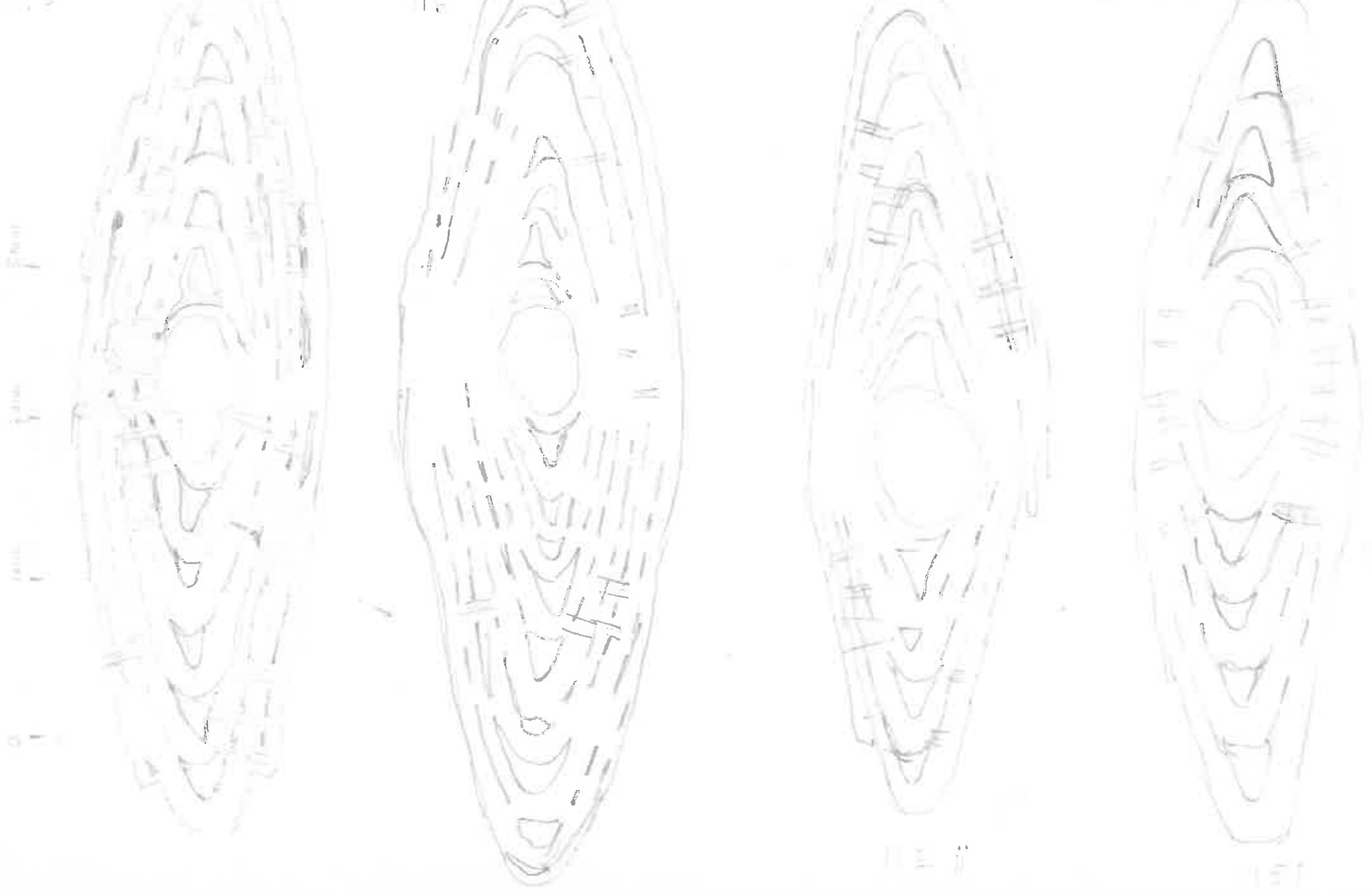


FIG 33

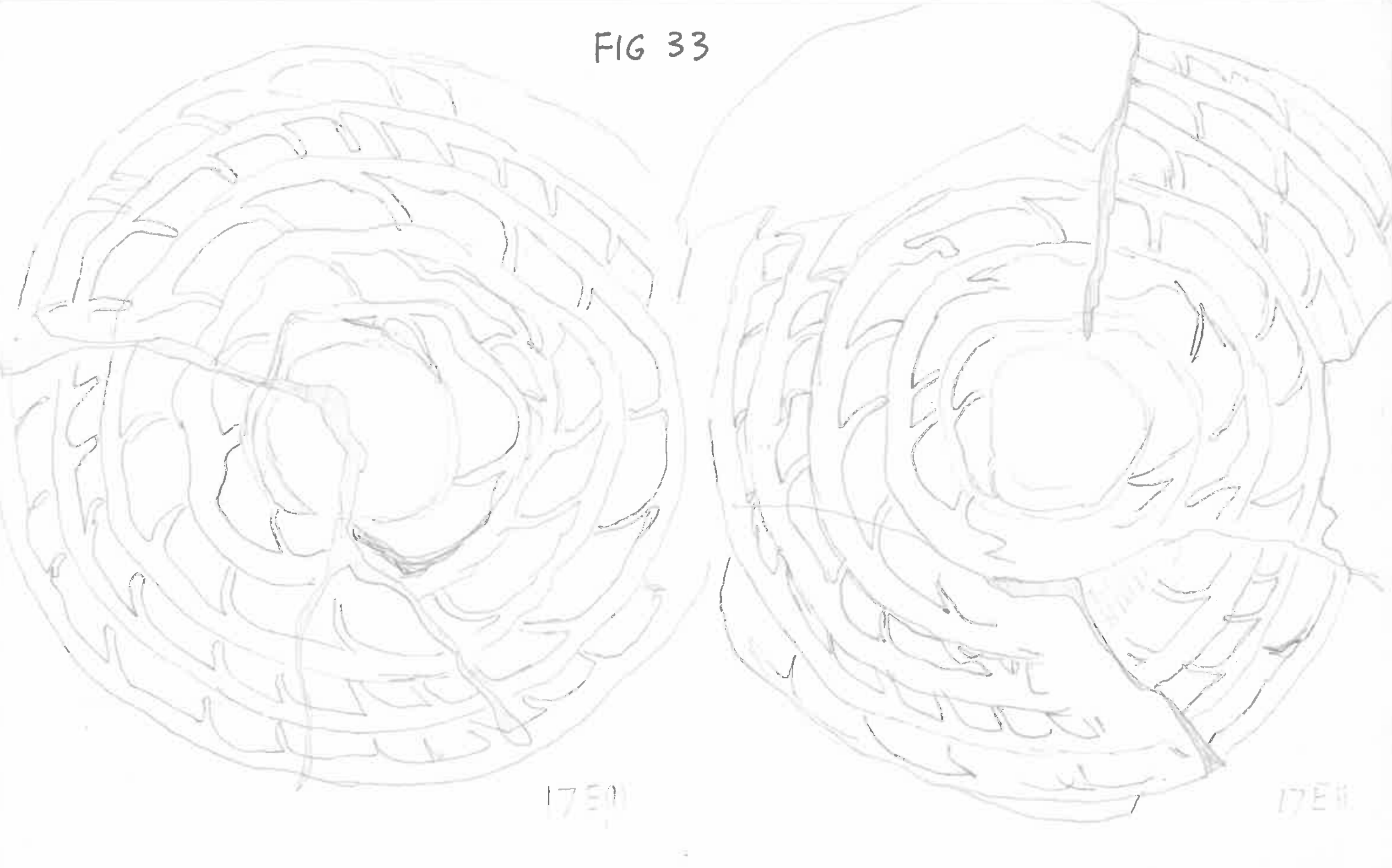


FIG 34

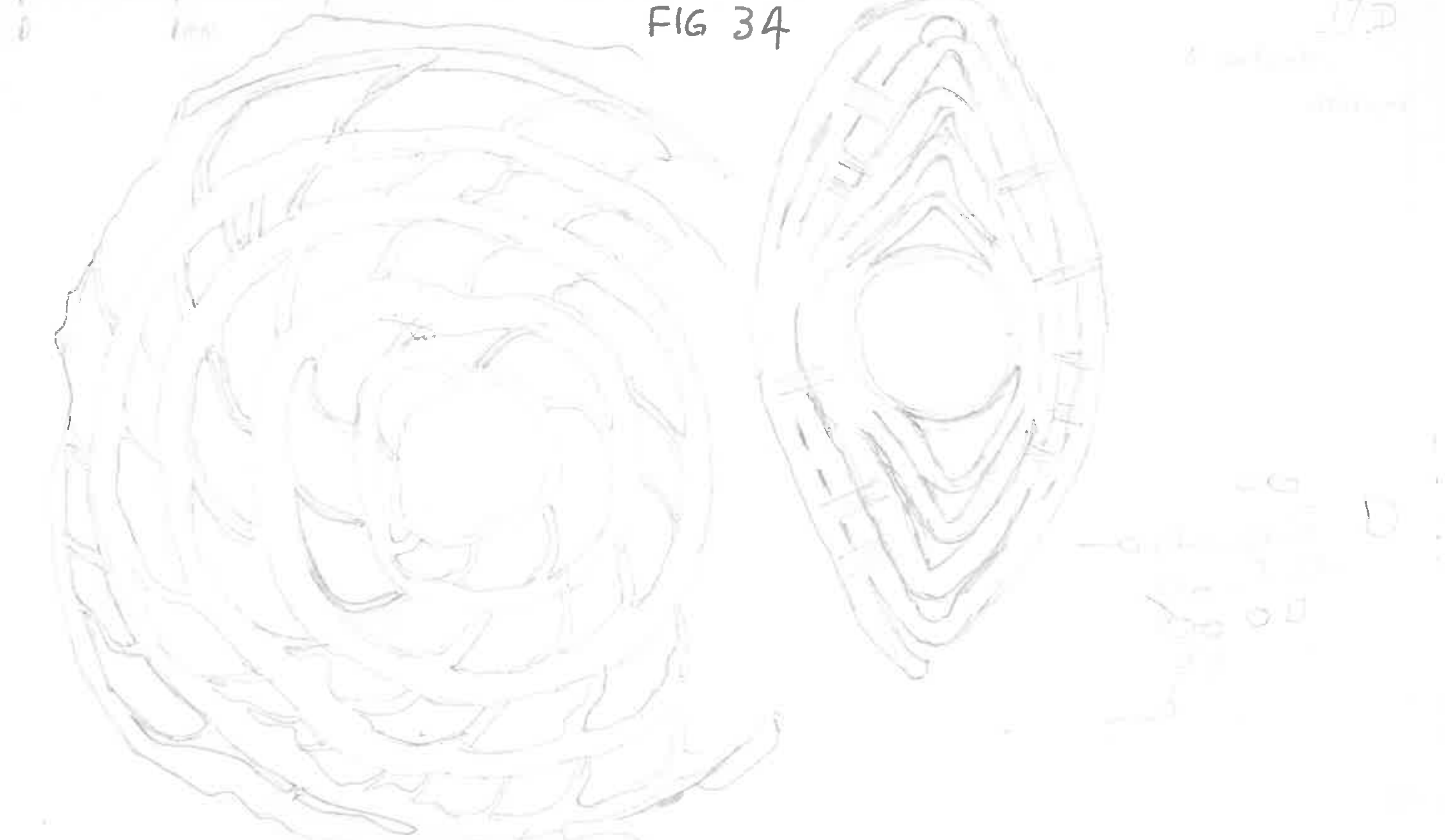
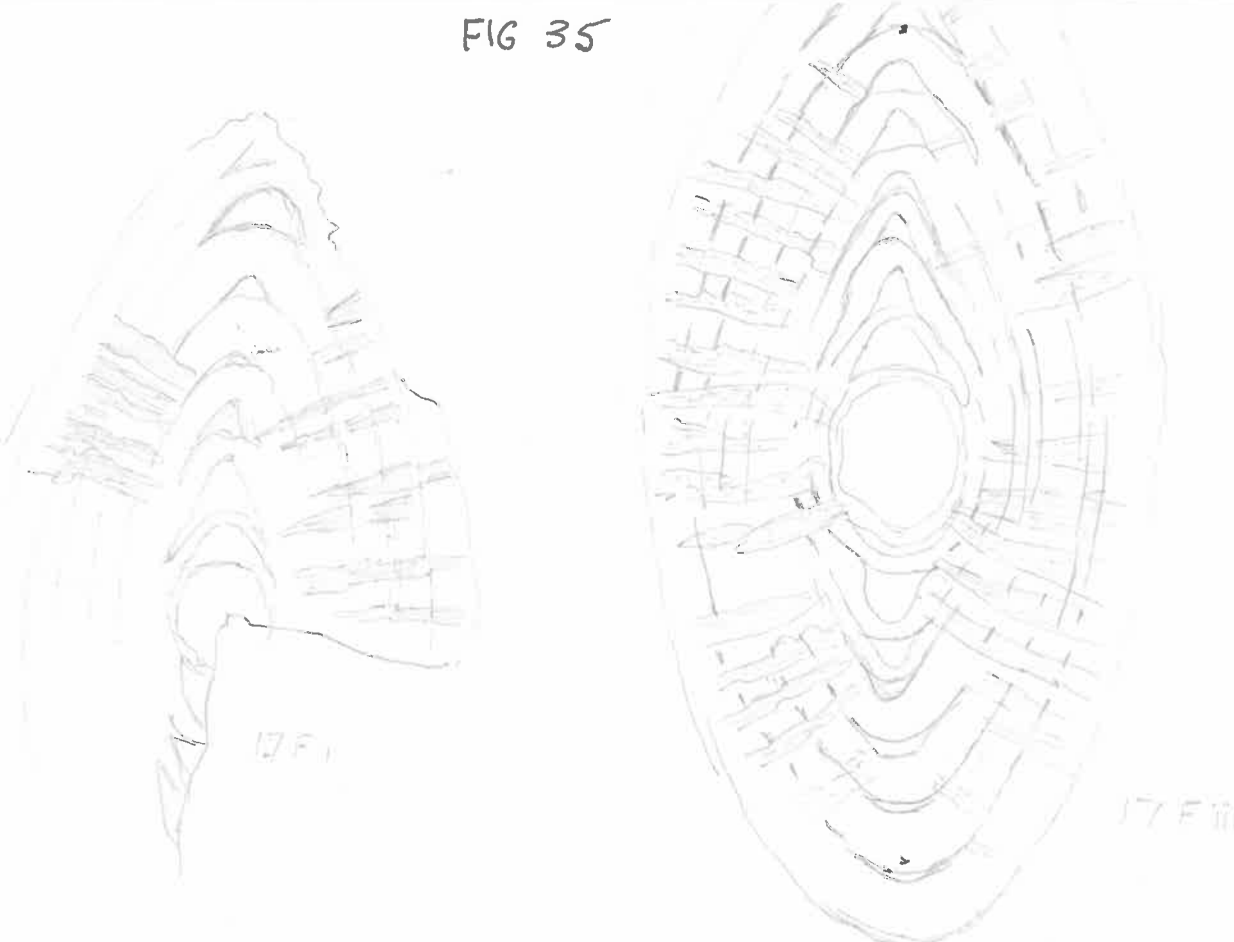


FIG 35



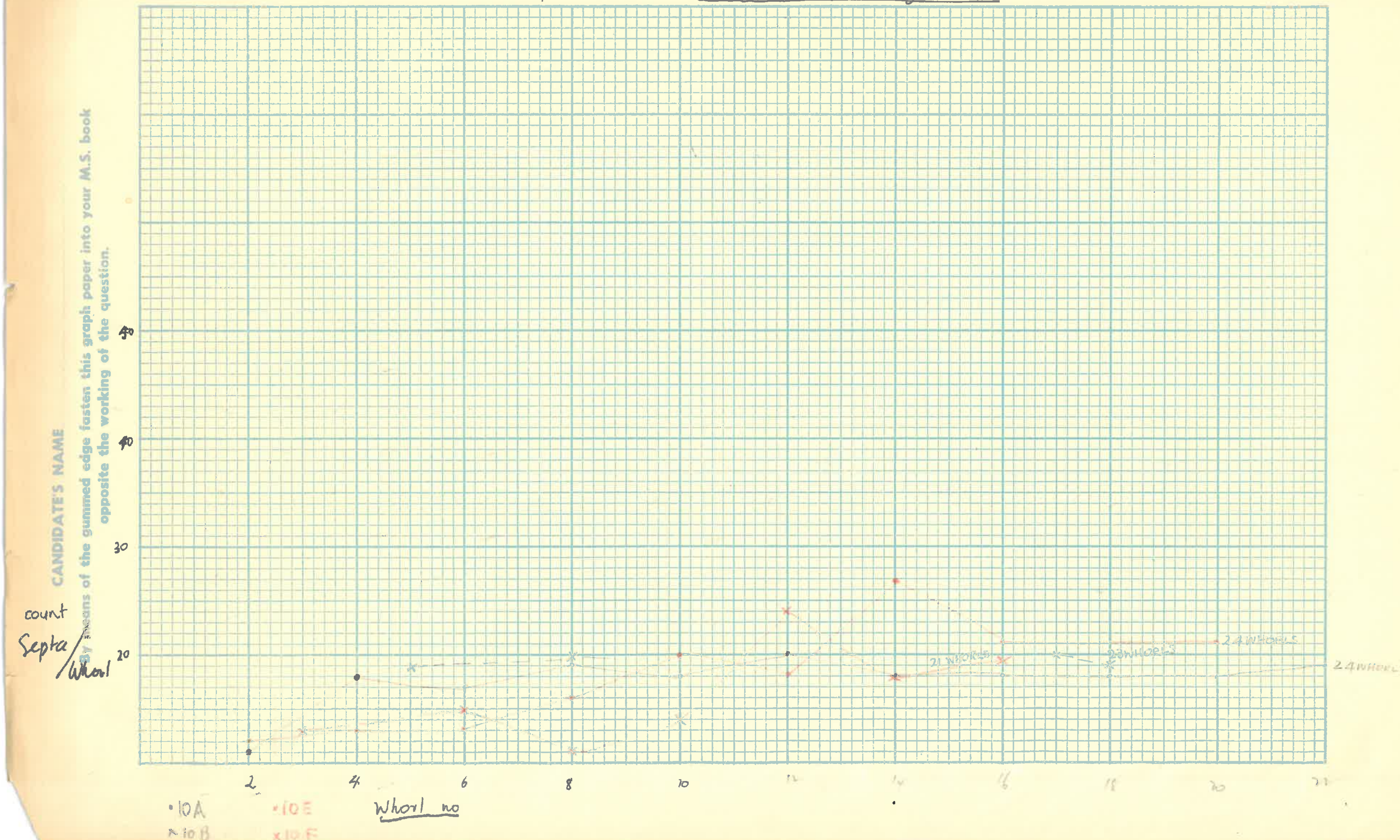
Diagrams illustrating the variability in the number of septa per whorl for ~~the~~ individual specimens of the species studied

The number of septa occurring in each successive whorl is plotted against the number of that whorl.

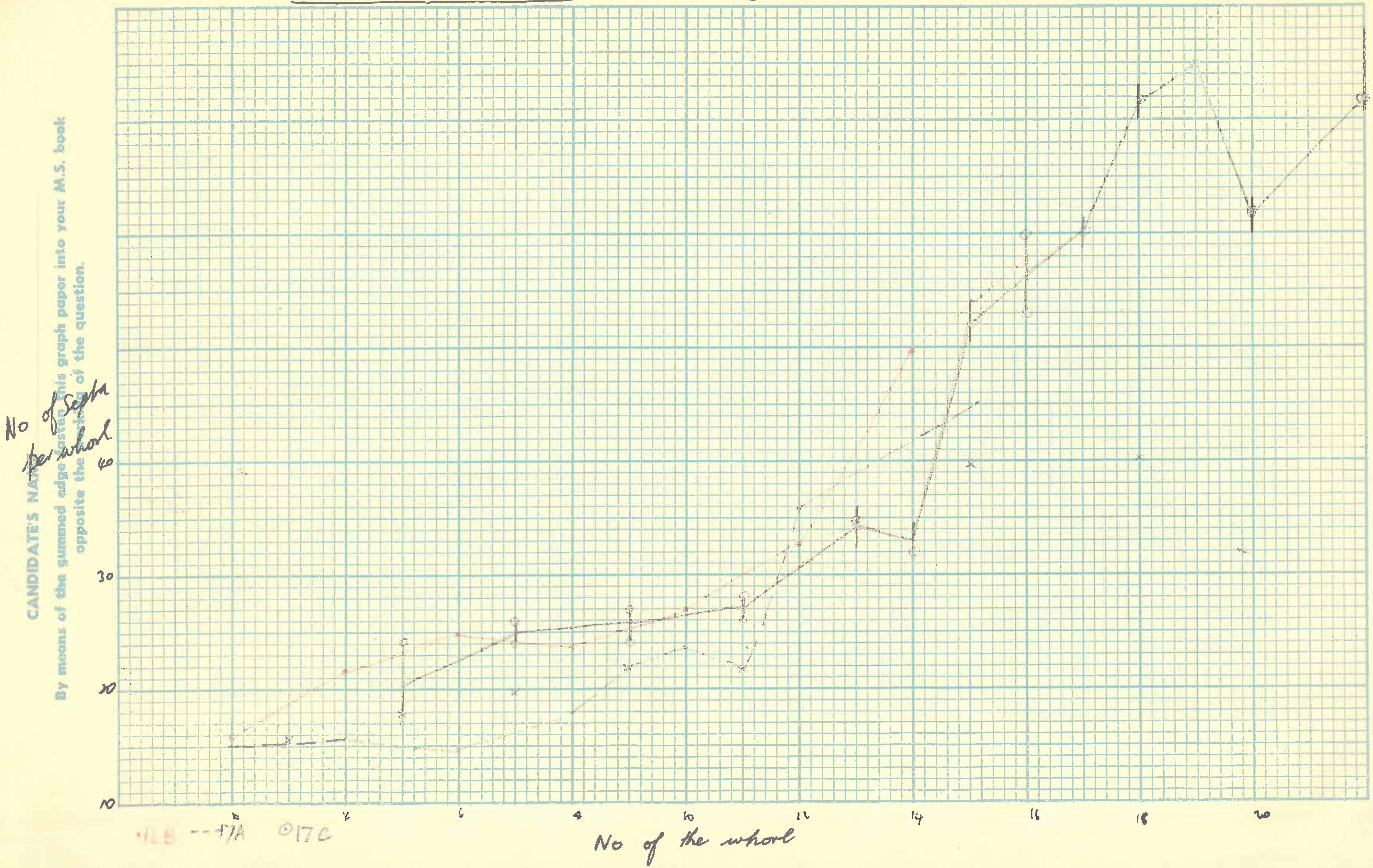
Bro. Septal count *Nummulites brongniarti* MICROSPHERIC FORMS

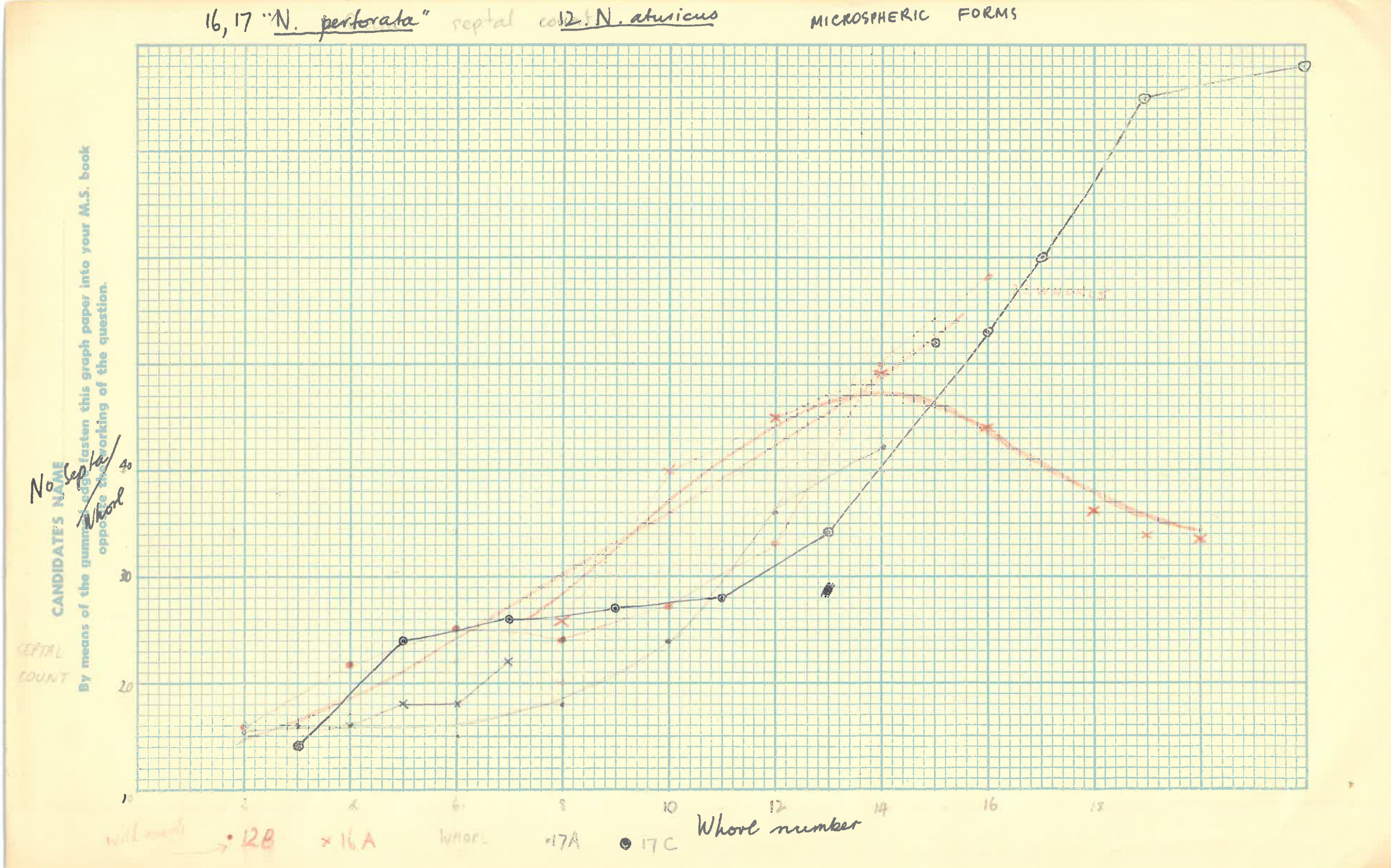
CANDIDATE'S NAME

By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.



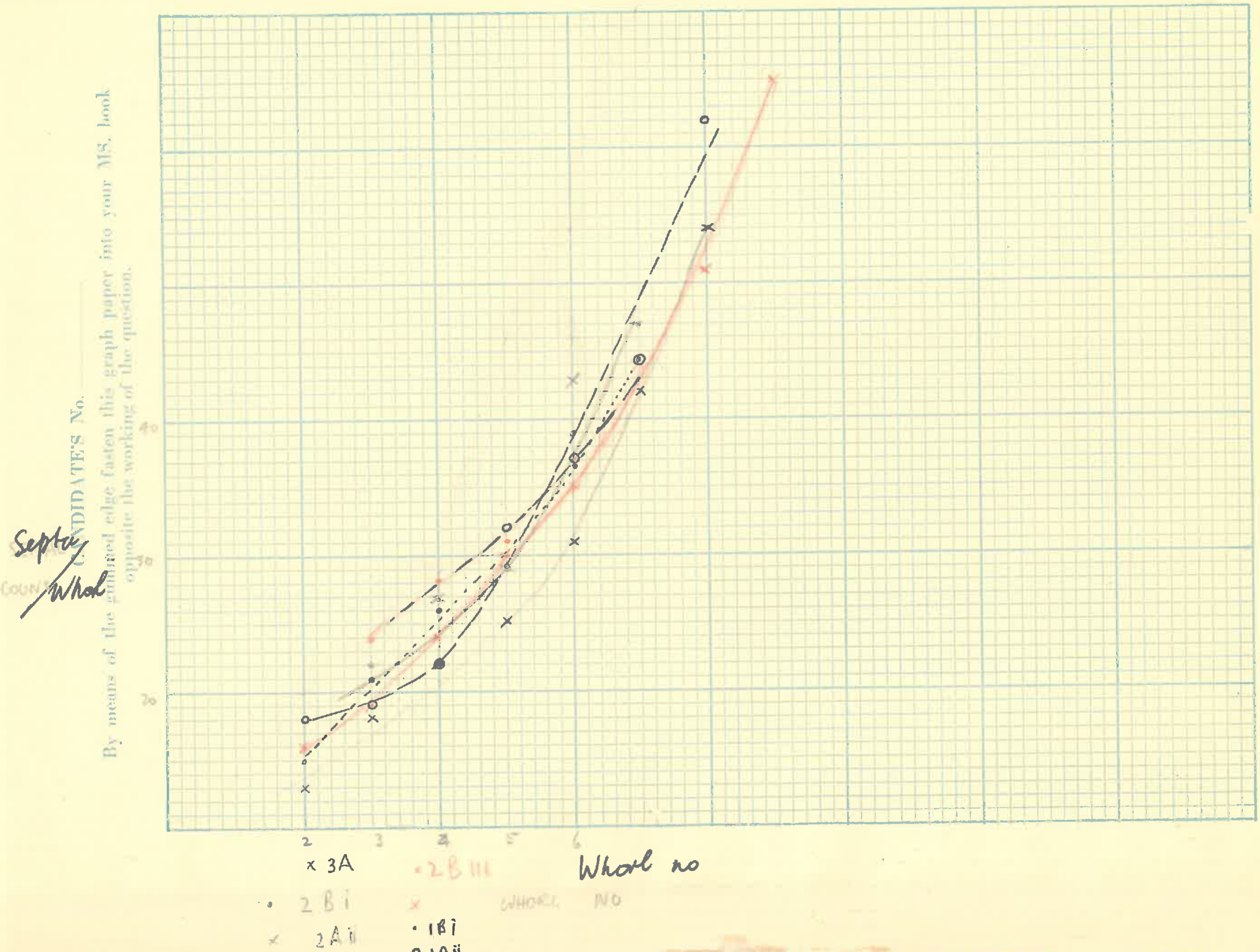
12. Nummulites aturicus 17. "N. perforata" MICROSPHERIC FORMS





16, 17 "N. perforata"
12. N. atusicus
MICROSPHERIC FORMS
No Septa/Whorl
10
20
30
40
2
4
6
8
10
12
14
16
18
Whorl number
• 12B
× 16 A
•17A
● 17 C
CANDIDATE'S NAME
By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.

N. planulatus septal count MICROSPHERIC FORMS



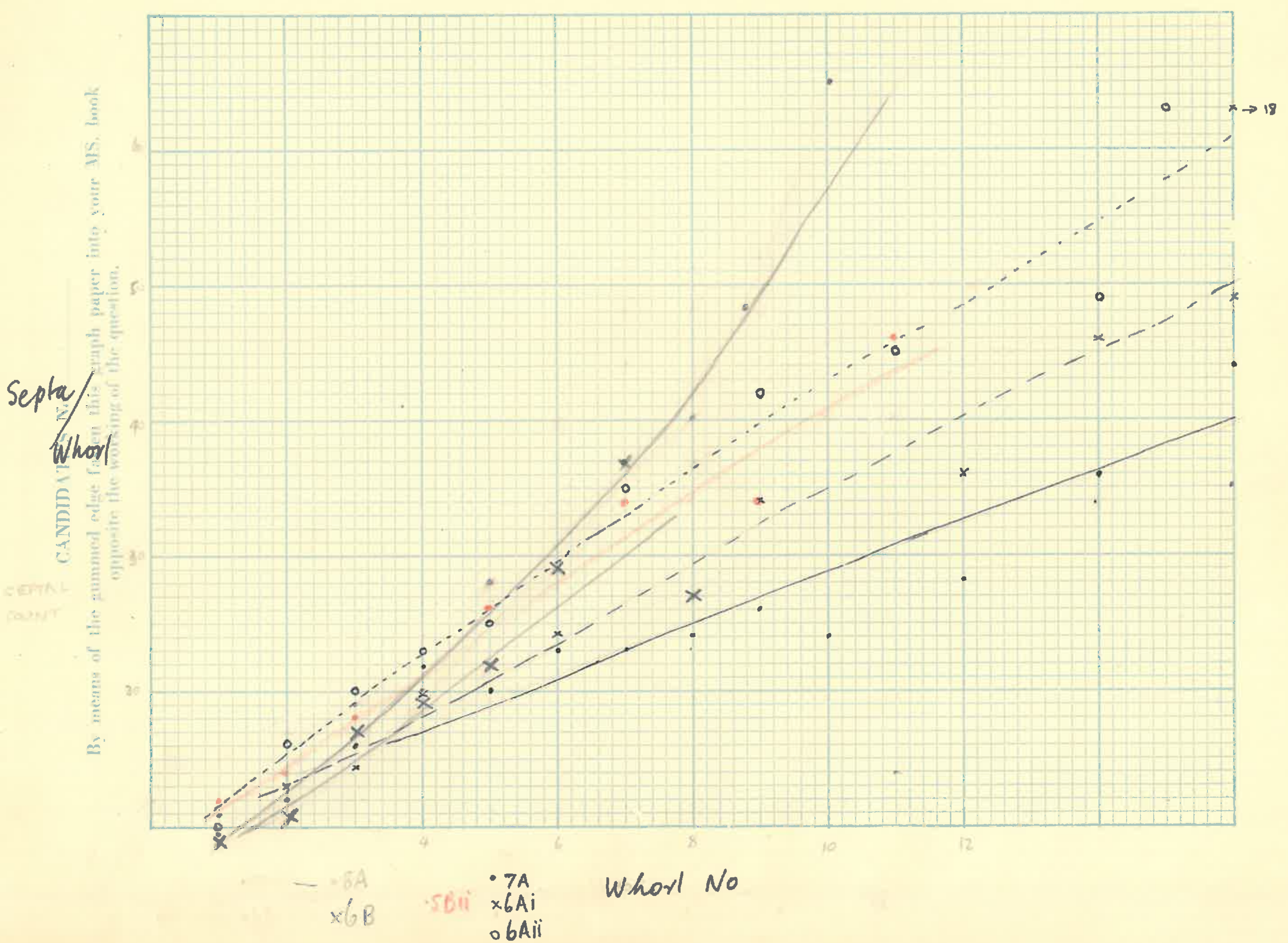
CANDIDATE'S No.

By means of the gummed edge fasten this graph paper into your MS. book opposite the working of the question.

8A Nummulites of aquitanicus

5 6,7 N. laevigatus.

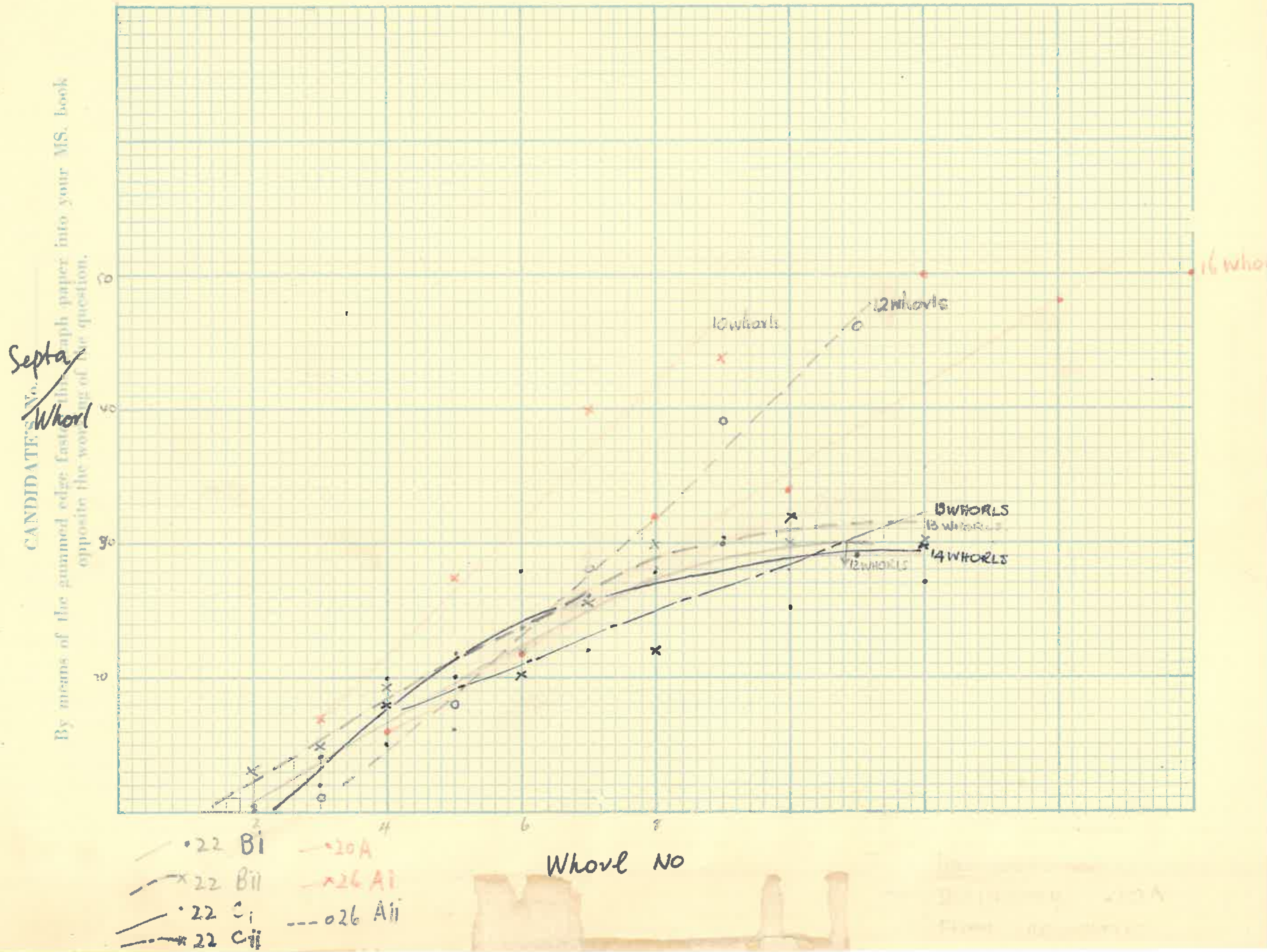
MICROSPHERIC FORMS



MICROSPHERIC FORMS.

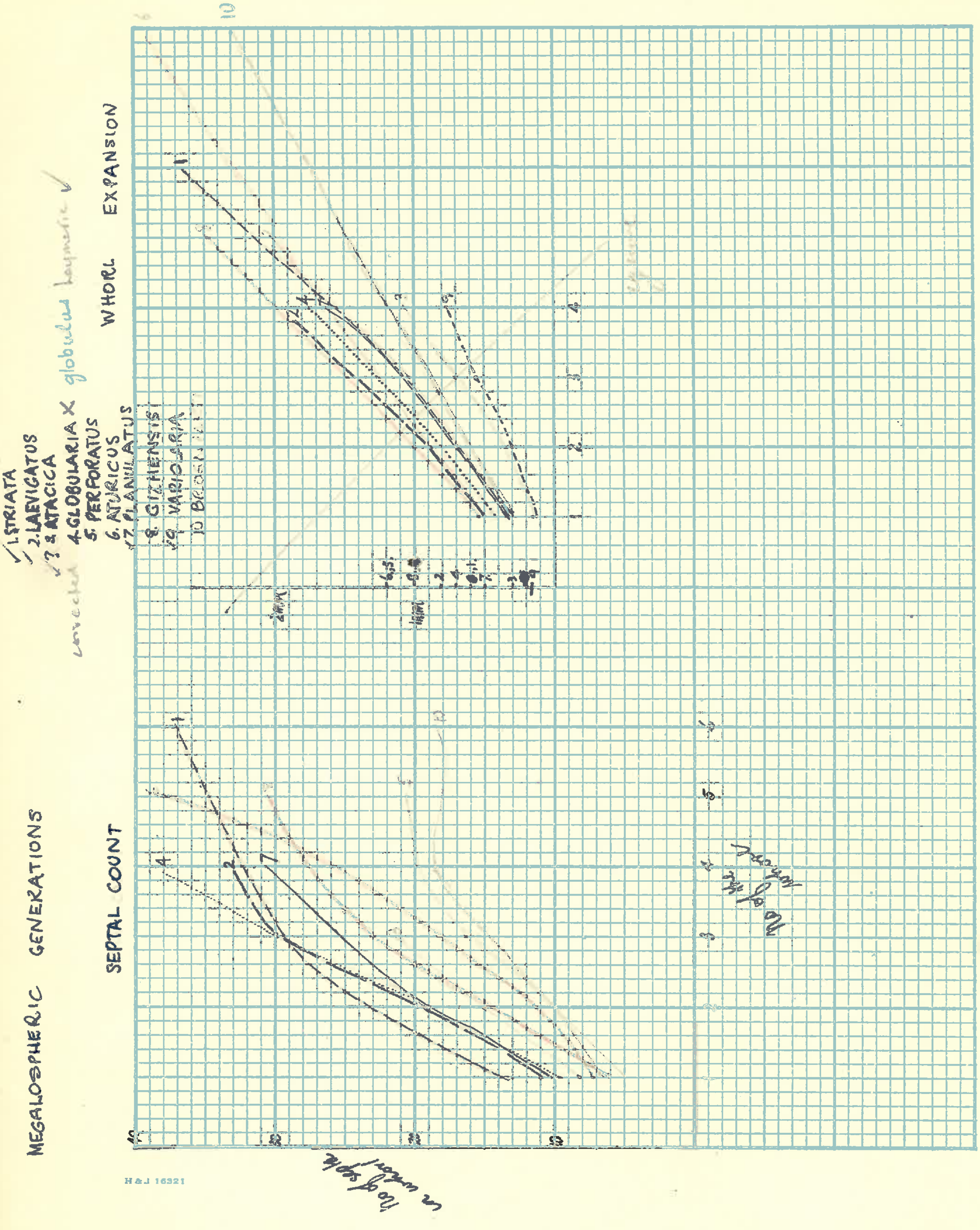
~~septa~~ septal count

22. Nummulites aff intermedius



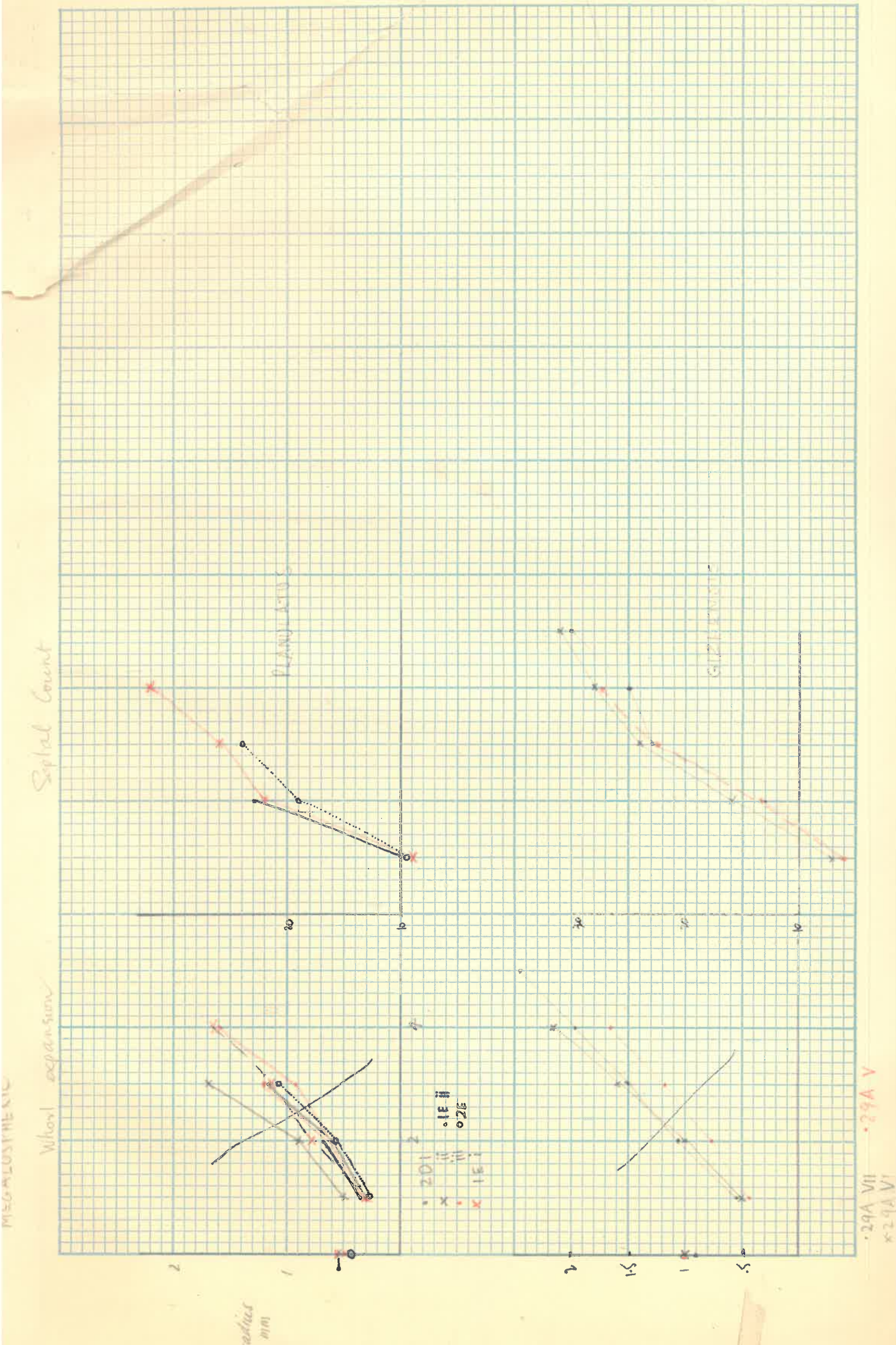
CANDIDATE'S No..........................

By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.



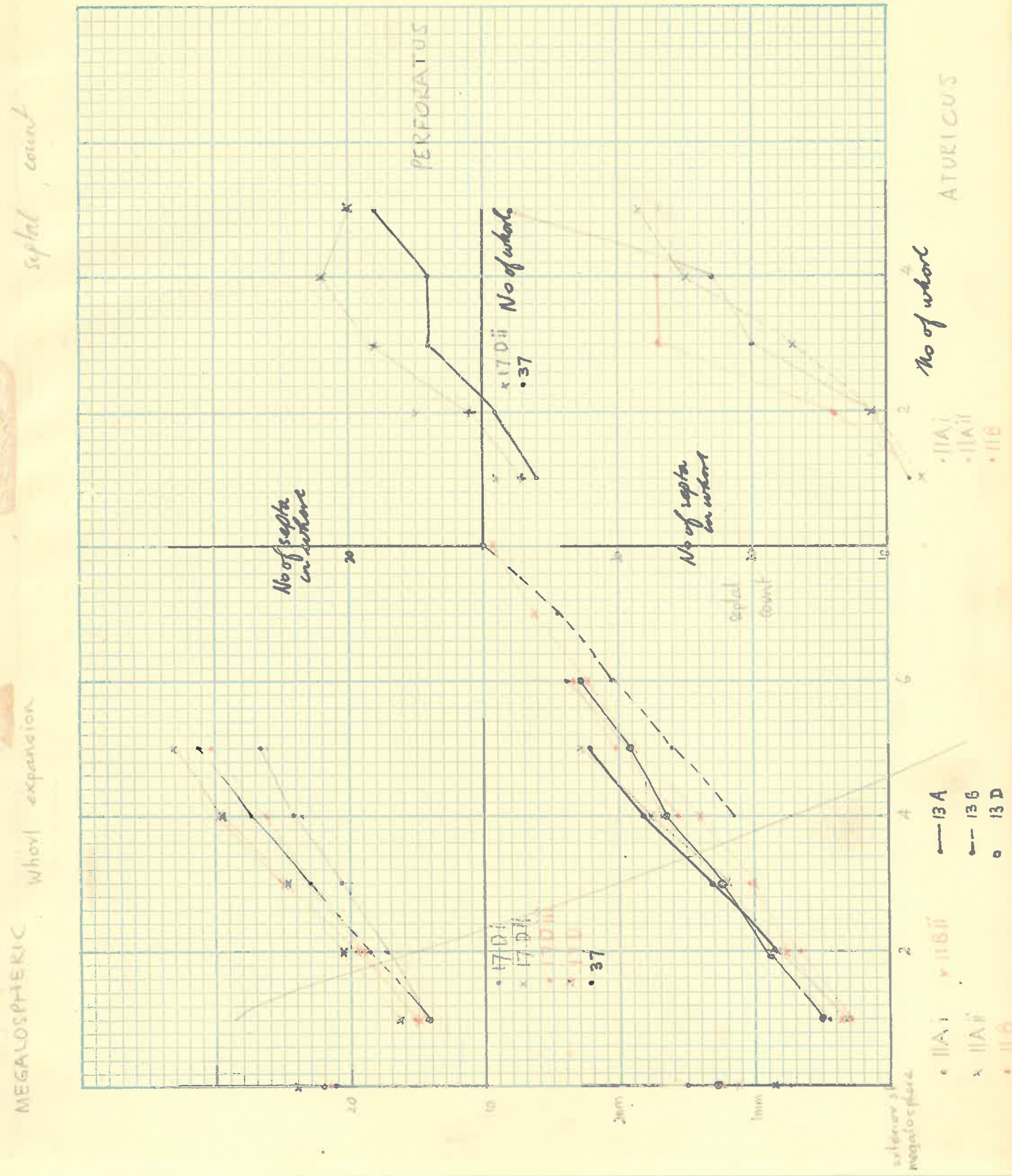
CANDIDATE'S NAME

By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.



CANDIDATE'S No. ____________

By means of the gummed edge fasten this graph paper into your MS. book opposite the working of the question.

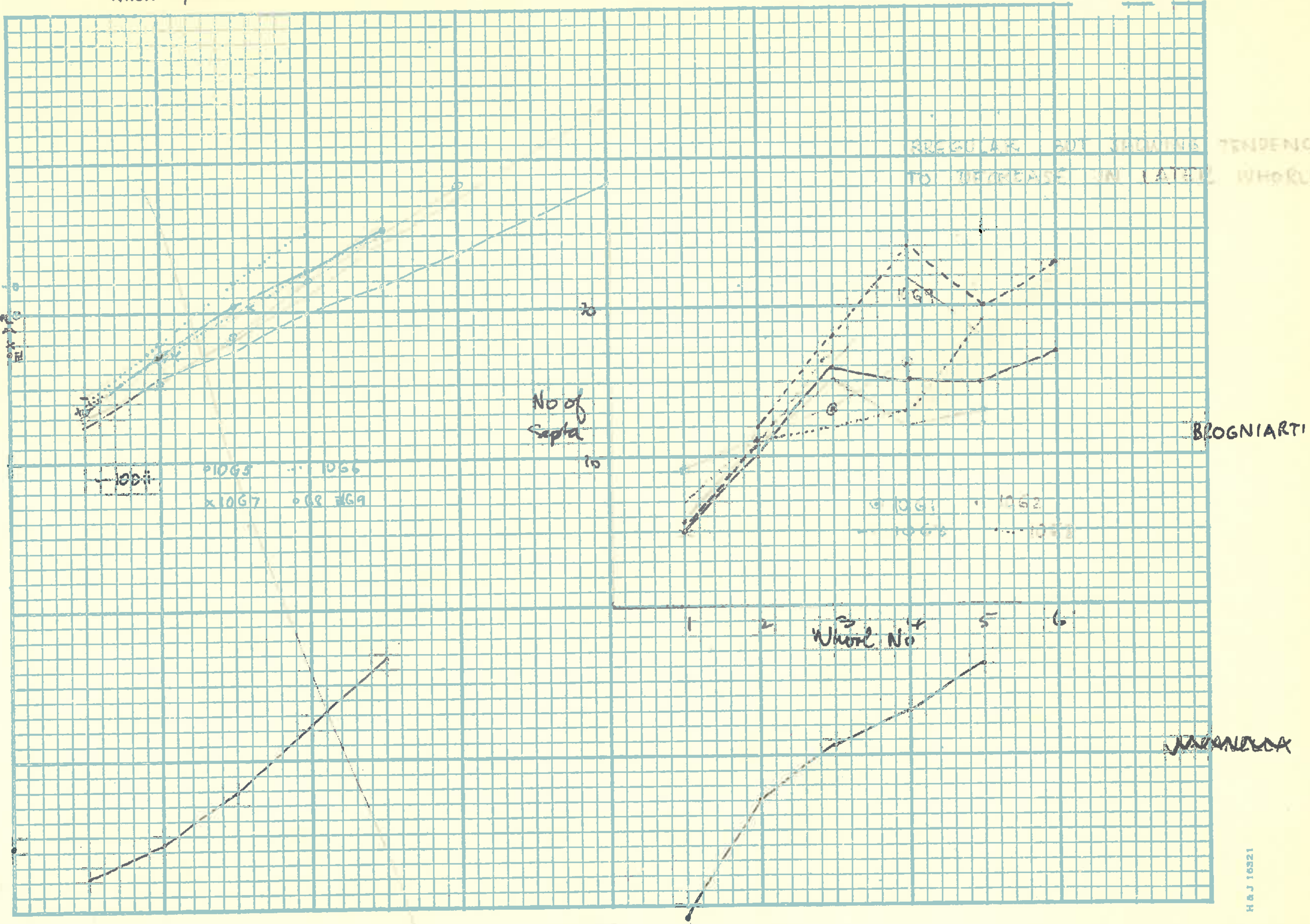


more specimens needed.

MEGALOSPHERIC

Whorl expansion

Septal Diagram



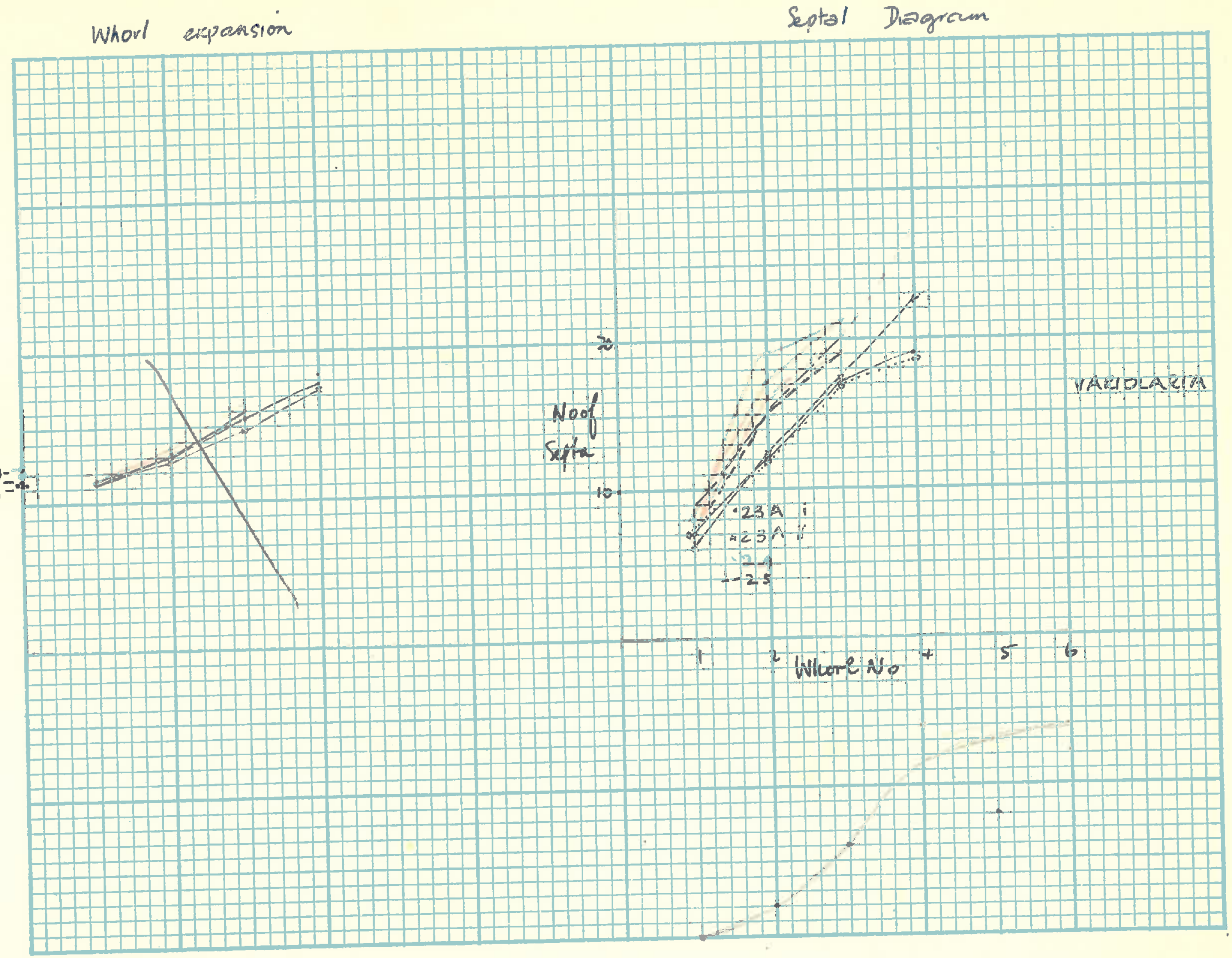
CANDIDATE'S No. ....

By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.

H & J 16321

·22 B

MEGALOSPHERIC



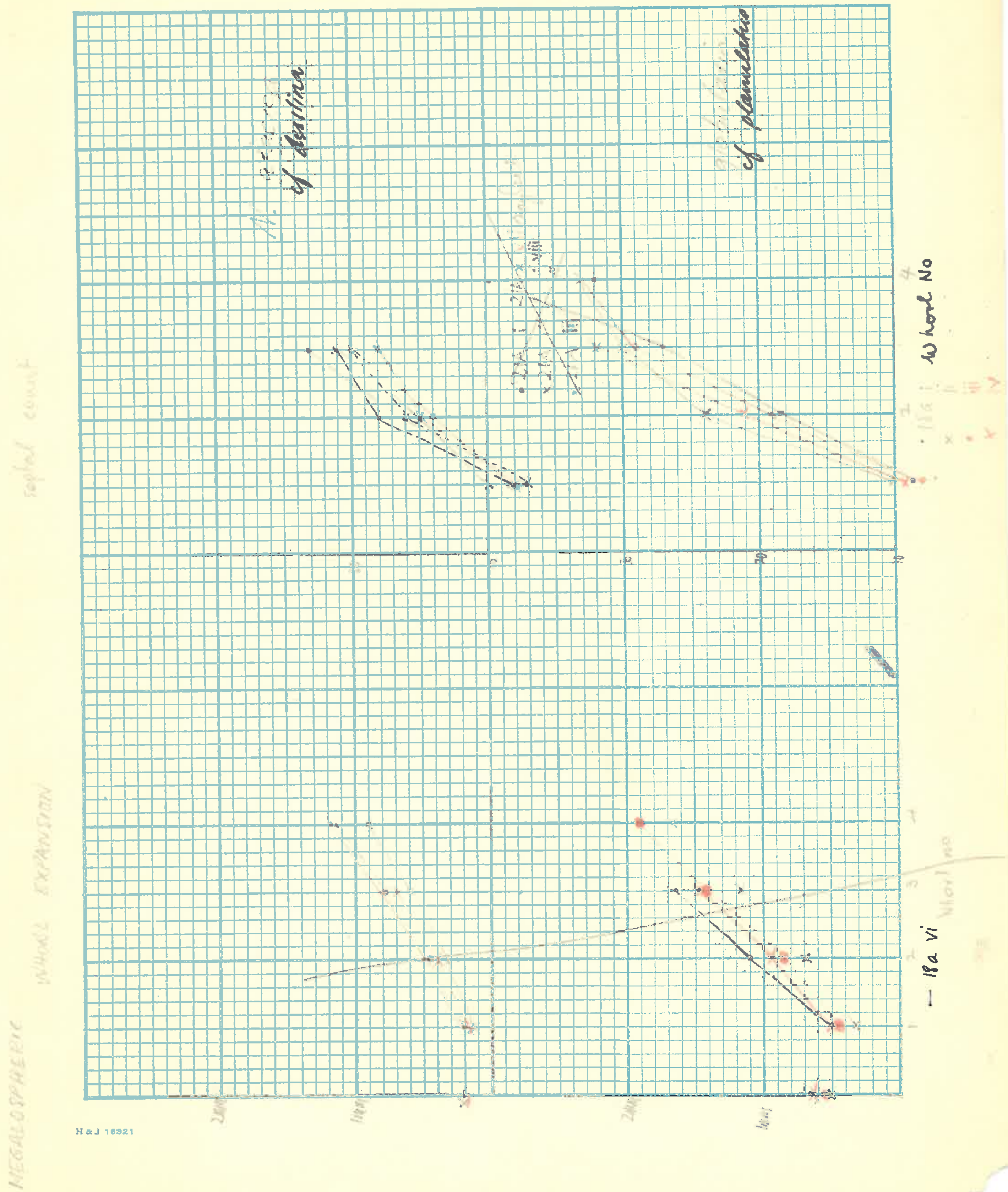
16 B

CANDIDATE'S No. ....

By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.

CANDIDATE'S No. ....

By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.



H & J 16321

CANDIDATE'S NAME

By means of the gummed edge fasten this graph paper into your M.S. book opposite the working of the question.