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MORPHOLOGICAL AND TAXONOMICAL STUDIES ON DOSINIA RADIATA (MOLLUSCA: BIVALVIA) FROM THE RED SEA

(With One Table and 4 Fig. & 6 Plate)

By

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دراسات مورفولوجيه وتصنيفيه على نوع دوزينيا راديانا /رخويات - ذوات المصراعين / جمعت من البحر الأحمر

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لقد بينت الدراسه ان محار دوزينيا راديانا يعيش مدفونا تحت سطح الرمال حتى ١٥ سم . والملمس الخشن للصدفه وشكلها يشبه الأنواع الأخرى التى تعيش مدفونه تحت الرمال .

ولقد اهتمت الدراسه باظهار الصفات التصنيفيه للصدفه والأجزاء الرخوه وهى كالآتى :-

للصدفه ستة اختلافات فى اللون . والسره تتجه بوضوح الى الامام واسفل . ورباط المصراعين من النوع الخارجى الخلفى ويوجد للداخل ميزاب عميق . وجهاز ربط الصدفه فى كل مصراع يتكون من اسنان رئيسيه تقابلها فى المصراع الاخر ميازيب تبيت فيها وهى صفات تميز الفوق عائله .

يوجد على السطح الداخلى للصدفه خطا البرنس الداخلى والخارجى بينهما جيب مثلث الشكل فى الجزء الخلفى السفلى تقابل جيب البرنس فى الأجزاء الرخوه والتى تحتوى على المزراقين الشهيقى والزفيرى والعضله المقربه الاماميه مساويه للعضله الخلفيه . وهذه صفات تميز العائله .

ولقد دلت الدراسه أيضا ان حافة البرنس تتكون من أربع ثنيات وليست ثلاثه كما هو موجود فى غالبية ذوات المصراعين . والتحام البرنس فى المناطق التى يلتحم بها بواسطة الثنيه الداخليه وهو من النوع (أ). وهى صفات تميز العائله .

ولقد بينت الدراسه ان هذا النوع يعيش على عمق كبير نسبيا مدفونا فى الرمال مما يجعل له مزرقان طويلان نسبيا يظهران على السطح أثناء امتدادهما . ورباط مصراعى الصدفه يكون دائما لأعلى وموازيا للسطح الرملى . وهذه الصفات مميزه لجنس دوزينيا .

ولقد بينت الدراسه ان الصدفه والاجزاء الرخوه لهذا النوع مستديره تقريباً مع ميل خفيف للحافه الخلفيه وهى من الصفات الخاصه لهذا النوع .

كما تبين ان القلب مكون من بطين واحد واذينين يفتح كل منهما فى البطين بواسطة فتحه جانبيه يحرسها صمام يسمح بدخول الدم ولا يسمح بخروجه . كما وجد تركيب يشبه البطين يقع خلفه داخل غشاء التامور ولكنه لا ينبض كالبطين ولا يتصل به أى تركيبات اخرى . وهو غير معروف سابقاً فى ذوات المصراعين ويحتاج الى دراسات اخرى للكشف عن هويته . والمزراقان الشهيقى والزفيرى يخرجان من جيب البرنس المثلث الشكل . والقدم يشبه الفاس وملائم للحفر فى الرمال وحافتاه الجانبيتان معرجتان ويحتويان على غدد مخاطيه تسهل وظيفته . والكلي تتركب من (٤) حجرات اثنتين على كل جانب وهى مقسمه بواسطة حواجز طوليه غير كامله . والجنسان منفصلان وحويصلات المنسل لكل منهما تنتشر على طول القناه الهضميه دون ان يكون لها تركيب خاص بها .

وحويصلات الخصيه تكون أقل فى الحجم وصفراء اللون فى حين أن حويصلات المبيض أكبر حجماً وبيضاء اللون . والجهاز العضلى يتكون من زوج من عضلات الصدفه وزوج من عضلات القدم .

هذه الصفات السابقه تميز العائله القندوفليه وجنس دوزينيا بالاضافه الى الصفات الخاصه لهذا النوع والتى تأكدت بتعريف العينات من المتحف القومى بوليز ببريطانيا .

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SUMMARY

Dosinia radiata is one of the common infaunal and sandy shore community of the Red Sea. It lives buried down to 15 centimeters below the surface level of the sand. The shape and ornamentation of the shell is similar to that of many sand burrowing bivalves. Dosinia radiata has six grades of colour. The beak of the shell is directed strongly forwards and slightly inwards. The ligament is external, of the opisthodetic type and seated in a deep nymph. The hinge apparatus of each valve consists of three cardinal teeth which fit in their own corresponding sockets on the other one. The pallial sinus is well developed, deep and triangular in shape. There is a heart-shaped (cordiform) lunule in the front of the beak. The adductor muscle scars roughly have the same size. The free mantle edge of D. radiata has four folds, where the inner fold is duplicated. The mantle fusion takes place by the two innermost folds of either sides (type A). The heart of D. radiata consists of a single ventricle and a pair of auricles. There is an unknown structure like ventricle, placed within the pericardial cavity and posterior to the ventricle. The siphons are long, conical shaped and lie within the pallial sinus. The foot is axe shaped, laterally commpresd and winkled from the two sides. The kidney is triangular, brownish in colour and consists of 4 chambers. The lumen of the kidney tubules contains black stones. The masculature consists of the adductors and pedal retractors. The sexes are separate and there is no external sexual dimorphism differentiating between them. Mature forms, show that the ovarian follicles are creamy yellowish and large in size in comarison with the yellowish and relatively small in size testicular ones. Controversy is regarding to the taxonomic status of the genus, specialy to the family. Some Authors assigned the genus Dosinia to the family Veneridae while others assigned it to the family Dosiniidae. The morphological charecters collected from the species are in accordance with the characters of the family Veneridae, genus Dosinia and the species radiata.

INTRODUCTION

The flesh of mussels is eaten and their shells were used for industrial purposes in various parts of the world. So, many countries in the world are cultivating mussels for their economic values. Members of the genus *Dosinia* have large size, interesting patterns of colour and high intensity of the population. They are distributed in different parts of the world as Indopacific, Red Sea, around Africa and British Isles, Norwegian Sea, Iceland and Mediterranean (*BARNARD, 1964; DELL 1964, TEBBLE, 1976; BERNARD 1983).*

Sandy coasts of the Red Sea have vast populations of burrowing bivalves which are adapted to the mode of this life. A review of literatures on the Red Sea bivalves revealed that they have attracted the attention of a few investigators. Of the few published papers in this regard, one can mention those of *GOHAR & SOLIMAN (1963, a, b, c)* investigated some of mytilid members with special reference to their boring organs. *SOLIMAN (1969, 1972)* studied some ecological aspects of some coral boring bivalves and new clavagellid bivalve. *ABOUL-DAHAB (1984)* studied the internal organization as well as the conchological characters of the mytilid bivalve *Modiolus auriculatus.* Recently, *ABOU-ZIED (1991)*, made a survey on some bivalves from the Red Sea and lakes of the Suez Canal.

Generally, most of the previous pubished work was concentrated on the conchological characters of some bivalves. These characters are not sufficient for the correct definition of the taxonomic status of the species. In bivalvia, however, investigators have found many taxonomic characters of the soft parts which can be taken into consideration during the systematic studies. Among those characters are type of lips, labial palps, the ligament, the relative size of the adductors, type of the stomach, the structure of the ctenidia and the relationship between crystalline sac and mid-gut. So, the anatomical studies in Mollusca have revealed their importance in the identifecation, classification and phylogeny. Thus, many of molluscs, including bivalves which were defined by the help of conchological characters, need reinvestigation based on anatomical structures to confirm their taxonomic status.

So, the present investigation deals mainly with the Morphological characters of the shell and soft parts of the mussel *Dosinia radiata* which could be interesting to provide additional support to the characters of the family and the genus and to explore more characters for the species and its phylogeny.

MATERIAL and METHODS

The specimens of *Dosinia radiata* used in the present study were collected from a single site on the Red Sea Coast. The collection site is a sandy shore located at 54 km south of Quesir City (26°30'N, 34°'E) on the Red Sea coast (Fig. 1, B). Specimens were collected from the field, at the time of low tide, 0,0 to 0.5 meter deep. Specimens are usually found totally buried in muddy-sandy buttoms.

Collection was done by using the hand to set underneath the mussel and pick it up. Alive samples of *Dosinia radiata* and other associated fauna were sorted, and picked up to be put separately in plastic containers containing sea water. Some alive specimens of *Dosinia radiata* were taken to a place near the shore to examine the natural colour of the shell and the soft' parts. Some specimens were fixed for the histological preparations. Other specimens were preserved in 10% aqueous formalin, and taken to the laboratory to be used for all studies needed.

Measurements of the shell were done using a Varnier while those of internal parts were made by calibrated ocular microscope. Drawings of the shell, soft parts were done with help of a camera lucida.

Organs to be sectioned were cut off from the body and placed into Bouin's solution for 24 hours. Fixed parts were then passed to a graded series of alcohol from 30 to 100%. They were cleared in xylene then embedded in paraffin wax. Sectioning was made by a microtome at 6-7μm thickness. Sections were stained using haematoxylin and eosin combination. Some sections were stained with Masson's Trichrome, Orcien, Southgat's mucicarmine, Best's carmine stains' and Periodic acid Schiff's reaction (PAS) for the demonstration of collagen, elastin, reticulin, mucine, glycogen and carbohydrates; respectively.

RESULTS

The mature venerid bivalve *Dosinia radiata* (Reeve, 1850), under investigation is a handsome molluse which is roughly circular in outlines of the lateral view, with a convex outer surface and a concave inner one (PL. 1, A, C). In a top view of the dorsal aspect of the whole mussel, the level of the maximum convexity appears lying dorsal to the mid point of the dorsoventral axis of the shell (PL. 1, B).

In its natural habitat, the species is usually found totally buried in a muddy-sand bottom. The specimens lie in the sand with the uppermost ligament, parallel to the surface of the sand while long siphons extend dorsally outside the sand surface.

Examination of a large number of the specimens has shown that there is a diversity in the colour of the outer suface of the shell. The colouration of the periostracum can be differentiated into six grades as follows:

1- Yellowish white shell with white umbones.
2- Yellowish white shell with brownish umbones.
3- Yellowish white shell, white umbones and brown, broad, radial rays extending from umbones to the ventral margin of the shell.
4- Yellowish white shell with brownish umbones and brown radial rays extending from umbones to the ventral margin of the shell.
5- Pale brownish shell and umbones.
6- Yellowish white shell with brownish, circular rays near the umbo.

The maximum shell length, height and width, recorded in the present study, are 7.7, 5.6 and 2.9cm; respectively, while the minimum values of the previous dimensions are 3.3, 3.7 and 1.9 cm; respectively. The average shell length, height and width of one hundred adult specimens are 4.67 (±0.469), 4.468 (±0.299) and 2.366 cm (≡0.205); respectively. The calculated ratios the previous dimensions are the following:

shell width	shell height	shell length
1	1.88	1.97

The present species, as any other typical bivalved mollusc, consists of the shell and soft parts.

I- The Shell:

The shell of *Dosinia radiata* consists of two lateral valves, one on each side, which are joined together dorsally by an elastic ligament. The shell is roughly circular in outlines (PL. 1, A), heavy and thick, weighing about 11.36 (±3.02) m. The two valves are equal in weight, length and height, and completely closed during rest of the mussel without the appearance of the siphons or foot. The shell has two distinct dorsal umbones or beaks projecting slightly above the point of contact of the dorsal margin of the two valves. Each umbo is small, tapering and lies slightly anterior to the middorsal point of the shell and identical to the opposite one.

The two umbones are directed strongly forwards and slightly inwards (PL. 1, A,B; Fig. 2, A,B). It is important to note that, the beaks are the oldest formed part of the shell which are encircled by the growth lines.

In a top view of dorsal side of the shell (PL. 1,B), there is a well developed and conspicuous depression at the front of the ligament termed as lunule. It is heart-shaped (cordiform) and placed anterior to the middorsal point of the shell at the front of the umbones. It varies in colour from yellowish to pale brownish, and measuring about 5.8 and 4.6 mm in length and maximum width respectively.

The sculpture of the outer surface of the shell is rough due to the presence of heavily and distinct concentric growth lines. The growth lines are fine, regular and concentric around the beaks and become rough and coarse towards the ventral margin of the shell (PL. 1,a).

The two shell valves are held together at their postero-dorsal margin by an elastic ligament measuring about 23.7 mm ($\pm$1.58) in length and 2.27 mm ($\pm$0.215) in width. The ligament is straight or slightly curved, seated behind the cardinal teeth and extending towards the posterior margin (PL. 1, C; Fig. 2,A). So, the shell can be termed as opisthodetic type *(OWEN, 1959)*. The ligament emerges from two opposite shallow and well developed grooves known as nymphs *(JONES, 1979)*: each extending along the postero-dorsal margin of each shell valve.

Microscopic observation reveals that the ligament is differentiated into a dark brownish outer layer and a light brownish inner one (Fig. 2, C). The outer layer is homogenous in appearance and has the same width through the course of running till its end. Its width is narrower than that of the inner one being about 0.17 mm. The inner layer is wide in the middle and decreases gradually in width towards its margins and measures about 1.6 mm in maximum width. The width ratio between the outer and the inner layers of the ligament is 1: 10; respectively. It is known that, the elastic ligament forces the two shell valves to open when the shell muscles (adductors) are relaxed.

The shell valves of *Dosinia radiata* are characterized by the presence of middorsal plate of dentition termed as the hinge. The dentition of each valve is formed of three distinct cardinal teeth which constitute the hinge apparatus of each valve (PL. 1, C,D; Fig. 2, A,B). The cardinal teeth of each valve are opposite to sockets in the other one to serve the interlocking between them.

The first cardinal or the anteriormost tooth of the right valve is delicate and small, measuring about 4.3 mm (± 0.203) width. It is elongated and roughly pyramidal shaped in the lateral view and ends by a narrow apex, near the apex of the second cardianl tooth. Its longitudinal axis is vertical on the plane of the base of dentition plate. The second cardinal tooth follows the previous one and lies in the middle. It is larger than the anterior one but smaller than the third cardinal tooth (Fig. 2, A,B). It has a nearly pyramidal shape in the lateral view, measuring about 4.3 mm long and 1.93 mm (± 0.29) broad at its base. Its longitudinal axis is nearly vertical on the plane of the base of dentition plate. The third cardinal tooth or the posterior one is the largest. It is elongated in shape and measuring about 6.95 mm (± 0.53) in its long axis and 3.53 mm (± 0.382) wide at its broad base. Its apex is divided into two parts. Its base extends toward the second cardinal tooth.

There are two distinct depressions between the three cardinal teeth of the right valve used for fitting of the cardinal teeth of the left one. The first depression which lies between the first and the second cardinal teeth fits for the first cardinal tooth. The second one is bordered by the second and the third cardinal teeth and fits for the second cardinal tooth. While the third cardinal tooth of the left valve lodges in a depression lying behind the third cardinal tooth of the right valve.

Table 1: The average dimensions (mm) of the cardinal teeth of the left and right shell valves of *Dosinia radiata*.

Tooth Number	Right shell valve		Left shel valve	
	Length	Width	Length	Width
1st cardinal tooth	4.31 (∓0.69)	1.57 (∓0.20)	3.42 (∓1.65)	1.65 (∓0.18
2nd cardinal tooth	3.02 (∓0.21)	1.93 (∓0.32)	3.21 (∓0.32)	2.59 (∓0.29
3rd cardinal tooth	6.59 (∓0.53)	3.530 (∓0.4)	6.20 (∓0.25)	1.09 (∓0.14

The inner surface of the shell valve is white coloured and varied considerably in the degree of concavity. The depth extends from the peripheral area to the middle of the valve. One can easily discriminate the place of muscle scars, pallial sinus and pallial lines on this surface (PL. 1, C; Fig. 2, A).

The scar of the anterior adductor muscle is located on the anterodorsal part of the inner surface of the shell valve. Its dorsal margin is close to the dentition plate of the cardinal teeth. It is elongate in shape, measuring about 5.4 and 13.5 mm in short and long axes; respectively.

The posterior adductor muscle scar is located on the posterodorsal part of the inner surface of the shell valve nearly opposite to that of the anterior adductor muscle. It dorsal side is narrow and continuous with a small posterior pedal retractor muscle scar. It is somewhate oval in outlines; and measuring about 6.2 mm and 12.3 mm in short and long axes respectively (PL. 1, C).

The small posterior pedal retractor muscle scar is tapering towards its dorsal pointed end which is near to the dentition plate. So, it is difficult to differentiate all margins of this retractor muscle scar (Fig. 2,A).

The anterior retractor muscle scar is small and lies on the dorsal margin of that of the anterior adductor muscle. It is difficult to discriminate all margins of the anterior retractor muscle scar because it seems to be mixed with the dorsal margin of anterior adductor muscle scar.

The pallial line is well marked on the inner surface of the shell. The posteroventral side of the inner shell valve shows a wide triangular and deep pallial sinus. The pallial sinus tapers in the dorsal direction to become narrow at its apex and to acquire a triangular shape. It measures about 18.0 mm in height and 12.6 mm in width at its broad base.

Examination of a vertical hand section through the shell shows that, it consists of the three normal layers, namely the outermost or periostracum, the middle or prismatic and the innermost or nacreous (Fig. 2,D). The periostracum is the thinnest one; being about 0.17 mm while the middle one is about 0.44 mm and the inner about 1.0 mm thick.

II- The Soft Parts:

The soft parts of *Dosinia radiata* are pale yellowish in colour which changes into creamy white after a long preservation in 10% formalin or 70% alcohol. The soft parts can be differentiated superficially into the following parts:

A) The pallial lobes.
B) The extrinsic muscles.
C) The kidney.
D) The heart.
E) The siphons.
F) The foot.
G) The gonads.

A) **The pallial lobes**

As in other bivalved molluscs, *Dosinia radiata* has two lateral pallial lobes, one on each side, covering the visceral mass, ctenidia, labial palps, kidney, siphons and foot. Each mantle lobe is in the form of a smooth flap having the same

outline of the shell valve; being nearly circular (PL. 1, E; Fig. 3, A).

The pallial lobes are fused together dorsally forming the mantle isthmus and posteroventrally between the siphonal and pedal openings. They are pierced anteriorly and posteriorly by anterior and posterior adductor and retractor muscles; respectively. There are two areas on the margins of the pallial lobes with free edges; the first opposing to the foot called the pedal opening while the other opposing to the siphons called the siphonal opening. The two openings measure about 38.11 mm (± 2.26) and 15.22 mm (± 1.37) in length; respectively (Fig. 2, E,F).

Each pallial lobe is atached to the corresponding shell valve with the shell muscles and pallial muscle fibers. The ventral part of the outer surface of each pallial lobe is marked with parallel or crossing over bundles of smooth muscle fibers forming a distinct area varying in width and measuring about 6.26 mm (± 0.975) in greatest width (Fig. 3, A).

There are two distinct and curved pallial nerves passing through the pallial muscular area. The inner nerve passes through the upper edge of muscular pallial area while the outer one passes through the middle part of the previous area.

Cross section shows that the inner surface of the peripheral edge of each pallial lobe is markedly differentiated into four pallial folds enclosing three shallow grooves (PL. 2,A). They are known as outer, middle and two inner folds. The outer fold is thin and closely associated with the inner surface of the corresponding shell valve. The middle mantle fold is thick and slightly long and very close to the outer one.

The inner mantl fold is subdivided into two folds, the distal inner fold and the proximal inner one. The distal inner fold is thick and heavily folded. The proximal inner fold is also thick and less folded than the distal one.

It is likely to deduce that, the anterior and posterior fusions of the mantle lobes take place by the union of duplicated inner folds. So, the fusion of the mantle lobes in the present species as in other members of Veneracea, belongs to type (A) (see *OKLEMANN, 1964 and PURCHON, 1955),* and not to the type (B) as mentioned by *YONGE (1957).*

Histological and histochemical studies show that each fold of the mantle lobe consists of a covering epithelium enclosing a connective tissue core. The extreme apical portion of the epithelial cells shows positive reactions to the basic stains (PL. 2, B), PAS (PL. 2, C), and mucoid detection (PL. 2, D).

The epithelium rests on a basal lamina enriched with collagenous and reticular fibers (PL. 2, B,C). The connective tissue core has diffuse collagenous and reticular fibers (PL. 2, B,C). It also contains granules which eact positively to both PAS and mucoid detections (PL. 2, C,D).

At the posteroventral area of the mantle lobe, on each side there is a remarkable triangular area known as the pallial sinus which covers the siphons (PL. 1, E,F; Fig. 3, A). The pallial sinus passes anterodorsally up to the middle of the mantle lobe with average length of 17.88 mm (± 1.55) and average width of 11.27 mm (± 0.767) at the broad base.

The histological section through the mantle sinus shows that, it consists of a covering cuboidal epithelium enclosing a bulk of longitudinal and circular muscle fibers (PL. 3, A,B). The circular muscle fibers run as a thin layer underneath the covering epithelium. The longitudinal bundles occupy the core of the mantle sinus, and they are separated from each other by trabiculae of circular muscle fibers which are extending from the two sides of the circular muscle layer (Fig. 3, A,B).

By removing the mantle lobes, the general viscera are exposed. One can easily distinguish the different parts of the visceral mass due to the difference in colouration. The kidney is dark brown while the foot and siphons are creamy yellowish, the digestive gland is grey and the ctenidia are brownish in colour (PL. 1, F).

B) The extrinsic muscles:

The musculature of *Dosinia radiata* can be divided according to the function into two main groups: The adductors and the retractors.

1- The adductor muscles: There is one pair of the opposing adductor muscles, the anterior and posterior which are roughly equal in size. They are cross between the two shell valves and serve to close the shell against the action of the elastic ligament (Fig. 3, C,D; 4, G,H).

The anterior adductor muscle is pale yellowish in colour, laterally compresed, elongated and transversely located at the anterodorsal region of the soft parts, piercing the two pallial lobes, and connecting the two shell valves together. The width of the anterior adductor muscle is greater than its length (Fig. 4, G), measuring about 12.3 mm (± 1.2) and 5.86 mm (± 0.44) in width and length; respectively. It consists of bundles of somooth muscle fibers and one can observe that the anteriormost muscular bundles are clearly shorter than the posterior ones; beimg 3.17 mm (± o.62) long; respectively. The

length of the bundles increases gradually towards the posterior end (Fig. 4,G).

The posterior adductor muscle is a compact mass transversely located in the posterodorsal part of the soft parts, piercing the right and left pallial lobes to connect the two shell valves together. It consists of transverse bundlles of smooth muscle fibers. The anteriormost bundles are longer than the posterior ones, measuring about 9.23 mm (± 1.43) and 3.19 mm (± o.52) in their anterior and posterior lengths respectively. The length of the bundles decreases gradually from the anterior edeg of the whole muscle twoards the posterior one (Fig. 4, H).

2- The pedal retractor muscle: Dosinia radiata has two anterior pedal retactor muscles and two posterior pedal retractor mucles (Fig. 4, E, D, F). The anterior one of each side arises from the anterior half of the foot. extending anteriorly and obliquely upward and sticking with the opposite pedal retractor muscle of the other side and then the closely attached part of the two anterior pedal ratractor muscles becomes forked again into two muscle bands and each is inserted into the corresponding shell valve dorsal to the anterior adductor muscle scar (Fig. 4, D,F). Each band is flattened, being 18.8 mm (± 1.13) ong 2.48 mm (± 0.2) wide and 1.9 mm (± 0.16) thick, on the average.

The posterior pedal retractor muscle of each side arises from the foot and passes obliquely upwards and backwards till it forms with the corresponding part of the posterior pedal retractor muscle of the other side a relatively narrow and long compact band. The latter passes upward and posterodorsally penetrating the kidney, before it bifurcates into two bands; one on each side of the visceral mass. The muscle band of each side is inserted into the corresponding shell valve above the place of insertion of the posterior adductor muscle. Each band measures about 25 mm long, 2.88 mm wide and 1.99 mm thick. It is important to note that, the muscle bundles of the two muscles are intermingled together within the tissue of the foot to cooperate for the pedal reactions.

Histological sections through the shell muscles show that they have a basic structure of longitudinal muscle bundles parallel to each other and joined together with connective tissue (PL. 3, C,D).

C) The Kidney:

the kidney or nephridum of *D. radiata* lies at the front of the posterior adductor muscle; extending anteriorly underneath the pericardium (Fig. 3, C,D). In a lateral view, it is roughly

triangular in outline, brownish in colour and measures about 12 x 9 mm in its maximum length and width; respectively. On removing the roof of the kidney, its interior structure is exposed (Fig. 4, A). The kidney lumen is separated with an incomplete medial septum extending between its anterior and posterior ends, dividing it into right and left sides. The lumen of each side has a vertical septal outgrowth arising from its floor and dividing it into two chambers (Fig. 4, A).

Histologically, the kidney consists of renal tubules which have an epitehelial lining of columnar cells. Interestingly, the lumina of the kidney tubules contain black stones which are concentrated mainly in the peripheral region (PL. 4, A,B).

D) The heart:

The heart of *D. radiata* consists of a single ovoid ventricle connected from each side with a triangular auricle (Fig. 4, B,C). The heart lies parallel to the general body axis, and hinge line, posterior to the stomach. It is enclosed within the pericardium. In alive specimens, the pericardium is filled with a transparent fluid and bounded by a pericardial wall.

The ventricle is an ovoid sac measuring about 3.4 and 2.44 mm in length and maximum width; respectively. As in other bivalves it is pierced by the rectum which extends within its cavity from the anterior end till it emerges out at the posterior end. It has been noticed that, the ventriclular and rectal cavities of the species under investigation are not connected at any place. Cross section through the ventricular wall shows that it consists of some muscle fibers which are scattered in all directions and not arranged in definite layers (PL. 4, C).

The auricles are light brownish, triangular sacs which lie laterally, one on each side of the ventricle (Fig. 4, B). Their narrow inner edges open into the ventricle by two oval auriculoventricular openings which are guarded by a pair of valves (Fig. 4, C).

Interestingly, there is an ovoid brownish sacculus lying posterior to the ventricle within the pericardium and penetrated by the rectum, it is separated by a distance of about 2.8 mm from the ventricle and measures about 4.3 x 3.3 mm in length and width; respectively (Fig. 4, B). In alive specimens, it does not contract or relax and does not show any vessels arising from or entering into its lumen. Histologically, its wall consists of muscle fibers scattered in all directions and not arranged in a definite layer (PL. 4, D). The

muscle fibers are less dense in it dense than in the ventricle (PL, 4, D). This structure has not so far described previously and so it needs further investigations to reveal its identity, structure and function.

E) The siphons:

Siphons in Bivalvia vary in the rate of extension, fusion together along their length and in the outer sheathing. *Dosinia radiata* has long siphons measuring about 12 cm when fully extended and 2 cm during rest. They are lying beneath the pallial sinus and extending out of the soft parts through the siphonal opening (PL. 1, Fig. 3, B,D). The basal halves of the siphons are formed by fusion of exhalant and inhalant openings which are separated in their distal halves only. The interior apertures of the two siphons are equal, rounded in shape and each measuring about 6 mm in diameter. While the exterior apertures are slit-like during rest and they are oval shaped during the siphonal extension. Each of the two siphons is conical in shape, creamy yellowish in colour. The exhalant siphon, which lies dorsal to the inhalant one, is slightly longer than the later during extention. There are black pigments scattered over the two exterior apertures while no tentacles are observed.

Histologically, the inhalant and exhalant siphons consist of an outer and inner columnar epithelium, enclosing connective tissue core which contains longitudinal, circular and oblique muscle fibers (PL. 5, A,D). Histochemical studies of siphons show that the contents of the apical part of the epithelial cells are positively reacted to PAS (PL. 5, C,D) and of mucoid nature (PL. 5, C,D). Also the connective tissue core contains collagenous and reticular fibers scattered in different directions.

Such structure of the siphons serves for their contraction and extension and their movement outside and inside of the animal body.

F) The foot:

The foot of *Dosinia radiata* lies along the ventral border of the visceral mass. It is large, axe-shaped, laterally compressed and about 3 cm in length. Its maximum width which is about 7 mm at the middle, decreases gradually towards its anterior and posterior ends where it becomes about 3 mm wide (PL. 6, E; Fig. 3, B,C,D). It is likely that, the uppermost part of the fooot is attached to the mantle and shell by the anterior and posterior retractor pedal muscles. The outer surface of the foot is marked by vertical ridges and grooves.

Histological and histochemical observations show that the foot consists of an outer folded ciliated covering epithelium enclosing a core of connective tissue supported with muscle fibres (PL. 6, A,B). The epithelium consists of ciliated columnar cells based on fibrous basal laminae (PL. 6, B,C,D). The apical parts of the latter cells show positive reaction with PAS indicating the mucoid nature of thier contents (PL. 6, C, D,). The basal lamina consists mainly of collagenous and reticular fibers (PL. 6, B).

The core of the foot consists of a connective tissue which contains longitudinal, circular, horizontal, transverse, and oblique muscle fibers. It contains collagenous, reticular and elastic fibers. The core also contains large numbers of blood sinuses. Such structure of the foot shows that it is well adapted for burrowing throughout the sand. Also, it may help in sorting food materials which pass on its surface from the inhalant siphon to the labial palps.

G- The gonads:

The sexes of *D. radiata* are separate. The gonad consists of a large number of gonadal follicles scattered manily around the posterior half of the stomach and intermingled with the digestive diverticula. The ovarian follicles are creamy whitish in colour and contains large number of ova. The testicular follicles are yellowish in colour and smaller in size than those of the ovary.

Taxonomic position of the genus *Dosinia* Scopoli, 1777:

The description of genus *Dosinia* has been subjected to confusion. In their papers, *SOOT-RYEN (1960), IREDALE and McMICHAEL (1962), DELL (1964), MOORE (1969) and DANCE (1974)* pointed out that genus *Dosinia* was described by Scopoli 1777. On the other hand, *BERNARD* in his recent catalogue (1983) reported that the genus *Dosinia* was described by GRAY, 1835. The taxonomic position with regard to te family has also been exposed to changing opinions. *BARNARD (1964),DELL (1983), VOKES (1967), MOORE (1969), DANCE (1974), KEEGAN (1974) and BERNARD (1983)* reported that the genus *Dosinia* is belonging to the family veneridae. While *SOOT-RYEN (1960) and IREDALE and McMICHAEL (1962)* assigned the genus *Dosinia* to the family Dosiniidae.

In his catalogue of living bivalves of Estern Pacific, *BERNARD (1983)* gave the following classification to the genus *Dosinia.*

Phylum	: Mollusca.
Class	: Bivalvia Linne, 1884.
Subclass	: Heterodonta Neumayr, 1884.
Order	: Veneroida H. Adams & A. adams, 1856.
Superfamily	: Veneracea Rafinesque, 1815.
Family	: Veneridae Rafinesque, 1815.
Genus	: *Dosinia* Gray, 1835.

Identification of *Dosinia radiata:*

The present material was identified as *Dosinia radiata.* The characters of the shell and soft parts of the present material were compared to those of the Superfamily, Family, genus and the species in the different keys and litratures of *SOOT-RYEN (1960), IREDALE and McMICHAEL (1962), BARNARD (1964), DELL (1964), VOKES (1967), MOORE (1969), DANCE (1974), KEEGAN (1974) and BERNARD (1983).* The result of this comparison shows that the present material is *Dosinia radiata.*

Some specimens of the species were sent to the section of Mollusca in British Museum in London. Mrs Kathie Way, Kindly identified these specimens as *Dosinia cf. tumida* (Gray). Because she was not sure, some photographs of the shell were sent to Dr. P. Graham Oliver, Assistant keeper of Zoology, National Museum of Wales, Cathays Park, Cardiff, U.K. He identified the species as *Dosinia radiata* Reeve and not *D. tumida.* He indicated that *D. tumida* has a steeply sloping posterior margin. Also, *ABOU ZEID (1991)* identified *Dosinia radiata* from shells collected from the Red Sea and Suez Canal.

Previous recording for *Dosinia radiata (REEVE, 1850)* is that of *VAILLANT (1865); ISSEL (1869); TILLIER and BAVAY (1905); MOAZZO (1939); BARASH and DANIN (1972) and HASSAN (1983)* cited by *ABOU ZEID (1991).*

Distribution of the genus *Dosinia:*

The genus *Dosinia* is remarkably widely spread throughout the world (Fig. 1, A). *BARNARD (1964)* referred to the genus *Dosinia* recorded in Senegal, Mauritania, Mouth of Congo, Angola, Aden, Madagascar, Indopacific, Red Sea, Mozambique and South Africa. *DELL (1964)* reported some recording to the genus in Tristanda Cunha, South Africa and Indopacific. *TEBBLE (1976)* referred to the genus *Dosinia* around British Isles, Norwegian Sea, Iceland, South Canary Islands, Iberian Peninsula, Mediterranean and along the coast of west Africa (*Senigal,*

Gabon and Ghana). While BERNARD (1983) reported some recording of genus *Dosinia* in south Atlantic and Galapagos Island. *D. radiata* is spread in Suez Canal, Suez, Red Sea and Indian Ocean *(abou zeid, 1991).* This wide distribution of the genus *Dosinia* is expected because members of the genus spawn and produce many of planktonic veliger larvae. This type of pelagic larva has a wide geographical range of distribution and is gnerally accepted as potentially leading to the wide dispersal of aquatic animals.

DISCUSSION

In considering the phylogeny of marine bivalves, the study of their morphology may be of considerable values. The present mussel *Dosinia radiata* is one of the common infaunal and sandy shore community. It lives buried down to 15 centimeters below the surface level of the sand. The shape and ornamentation of the shell is similar to that of many sand burrowing bivalves. The shell is heavy and thick with dense concentric growth lines that give it a rough appearance. *NARCHI (1974)* reported that the thickness of the shell and its roughly surface are only characters that can be specialized for mechanical boring in sand. *Dosinia radiata* has six grades of colour but with no differences in morphology. Also, their electrophoretic band analysis and their chromosomal number are the same *YASEEN* et al., in press).

The external surface of the shell has two tapering beaks (umbones) lying slightly anterior to the midline of the shell length and directed strongly forwards and slightly inwards. The ligmaent is external, of the opisthodetic type and seated in a deep nymph. The hinge apparatus of each shell valve is consisting of three cardinal teeth which fit in their own corresponding sockets on the other one. The pallial sinus is well developed deep and triangular in shape. Such characters are in accordance with those mentioned by *MOORE (1969) and TEBBLE (1976)* for members of the superfamily Veneracea.

The shell of the present species is equivalved and equilateral. There is a heart-shaped (cordiform) lunule in front of the beak. The adductor muscle scars roughly have the same size. These characters were mentioned by *TEBBLE (1976) and FISH and FISH (1989)* for the family Veneridae.

Unlike other genera of Veneridae, the present bivalve is a comparatively deep burrower with long siphons. The shell lies in the sand with the ligament uppermost and parallel to the surface of the sand. These characters agree with those mentioned by *ANSELL (1961)* for the genus *Dosinia.*

The outlines of the shell and the soft parts of the mussel under investigation are rounded and their posterior margins are steeply curved. This charater is in agreement with the identification of P. graham oliver (Pers. Comm.) for the species *radiata.*

Generally, the mantle lobe of many Bivalvia has three peripheral folds and the fusion between the two lobes takes place by the innermost mantle folds and therefore, it corresponds to type A *(YONGE, 1957).* Such number of the mantle folds and the fusion type are found in many bivalves such as: *Pseudopythina subsinuata* (Leptonacea), *Limnoperna fortunei* (Mytilacea), *Polymesoda* (Gelonia) *erosa* (Corbiculidae) and *Gaimardia finlayi* (Gaimardiidae) *(MORTON, 1972, 1973, 1976, 1979).* On the other hand, *JONES (1979),* found in other Venerid bivalves, that they have four mantle folds.

The free mantle edge of *D. radiata* as in other veneraceans has four folds. *OCKLEMANN (1965),* studied the development of the venerid *Venus striatata* and concluded that the inner fold is duplicated and the mantle fusion takes place by the two innermost folds of either side. This type of fusion as in other veneraceans is not belonging to type B *(YONGE, 1957),* but to type A. *PURCHON (1955)* corrected the fusion type of the mantle edge of *Petricola pholadiformis* by the two innermost folds of the two sides to be of the type A. *OLDFIELD (1955)* studied two species of Ericinidae and concluded that the free mantle edge of *Lasaea rubra* has three folds while that of *Turtonia minuta* has four folds. Hed added that the inner fold of the latter species is duplicated.

The heart of *D. radiata* has a typical bivalved structure. It consists of a single ventricle and a pair of auricles. The ventricular wall is thicker than that of the auricle, which lacks the muscle fibers. *Chaudhry and NARAIEN (1972)* reported that, the comparatively thick venticular wall and its muscular nature is because the auricle has to pass blood into a wide auriculoventicular aperture to the closed ventricle, while ventricle has to force blood to a narrow aorta.

The wall of both ventricle and auricle lacks endothelium. *MOLTLEY (1933),* (cited by *CHAUDHRY* and *NARAIN, 1972),* considered the absence of endocardium in the heart of mollusca is significantly helpful in marking the cardial tissue more sensitively to the cehmical substance of blood.

Interestingly, there is a structure like the ventricle, placed within the pericardial cavity and posterior to the ventricle. It is separated from the ventricle by a space about 2.8 mm long. As far as can be ascertained, this structure has not been mentioned before by any author for bivalves. Also, its

function is not known and needs further investigations to reveal its identity, structure and function.

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ABREVIATIONS

AAM : Anterior adductor muscle.
ABZ : Apical basophilic zone.
APRM: Anterior pedal retractor muscle.
CE : Ciliated epithilium.
CT : Cardinal teeth.
DP : Dentition plate.
ES : Exhalant siphon.
F : Foot.
ID : Inner Demibranch.
ILL : Inner layer of ligament.
IS : Inhalant siphon.
KT : Kidney tubules.
LA : Left auricle.
LLS : lateral left septa of kidney.
LU : Lune.
MF : Muscle fibers
MS : Median septa (Muscle sheath).
OD : Outer demibranch
OPl : Outer pallial line.
PAS : Posterior adductor muscle (scar)
PF : Proximal inner fold.
PPRM: Posterior pedal retractor muscle.
R : Rectum.
RC : Right chambers of kidney.
S : Shell (Stomach).
SO : Siphonal Opening.
U : Umbo.
VS : Ventricle like structure.
2 : Prismatic layer of the shell.

AA : Anterior adductor scar
AP : Anal papilla.
C : PAS positive contents.
CF : Collagenous fibers.
DF : Distal inner mantle fold.
E : Epithelial sheath.
EX : Exhalant siphon.
FE : Folded epithilium.
ID : Inner demibranch.
IPS: Inner pallial line.
K: Kidney.
L : Ligament.
LC : left chambers of kidney.
LRS: Lateral right septa of kidney.
M : Mantle lobe.
MMF: Middle mantle fold.
MU : Mucoid.
Oll: Outer layer of ligament.
P : Pericardium.
PE : Periostracum.
PM : Pallial muscle.
PS : Pallial sinus.
RA : Right auricle.
RF : Reticular fibers.
SE : Supra axial extension.
ST : Stone of kidney.
V : Ventricle.
1 : Periostracum of the shell.
3 : Nacreous layer of the shell.

EXPLANATION OF FIGURES

Fig. 2.

(A) A camera lucida drawing of the inner surface of the left shell valve of *D. radiata* showing the anterior adductor muscle scar (AAS), cardinal teeth (CT), inner pallial line (IPL), ligament (L), outer pallial line (OPL), posterior adductor muscle scar (PAS), posterior pedal retractor muscle scar (PPR) and umbo (U).

(B) A camera lucida drawing of internal surface of the apical part of the right shell valve showing the cardinal teeth (1, 2 & 3), (CT), dental plate (DP), ligament (L) and umbo (U).

(C) A camera lucida drawing of the ligament structure, showing its two layers, the inner (ILL). The outer (OLL), and the uppermost layer is periostracum of the shell (PE).

(D) A camera lucida drawing of a hand section through the shell showing t three layers; periostracum (1), prismatic (2) and nacreous (3).

(E) A camera lucida drawing of the ventral aspect of the mussel showing the foot (F) and the pedal opening (PO).

(F) A camera lucida drawing of the postero-ventral aspect of the mussel showing the siphons; exhalant (ES), inhalant (IS) and the siphonal opening (SO).

Fig. 3.

(A) A camera lucida drawing of the lateral aspects of the mussel after t removal of the right shell valve to show the anterior adductor muscle (AAM), mantle lobe (M), posterior adductor muscle (PAM), pallial sinu (PS) and pallial muscles (PM).

(B) A camera lucida drawing of the lateral aspects of *Dosinia radiata* af the removal of the right shell valve and the right mantle lobe showing the anal papilla (AN), exhalant siphon (ES), inner demibranch (ID), inhalant siphon (IS), kidney (K), outer demibranch (OD), rectum (R), suspensory membrane (supra-axial extension) (SE).

(C) A camera lucida drawing of the lateral aspects of *D. radiata* after removal of the right shell valve, right mantle lobe, and right gill demibranchs, showing the digestive gland (DG), labial palp (LP), gonad (G), rectum (R) passing through the structure like-ventricle structure (SV) and ventricle (V).

(D) A camera lucida drawing of the lateral aspects of the mussel after removal of the right shell valve, right mantle lobe, right gill demibranchs, gonad, and digestive diverticula, showing the crystalli sac (SC), exhalant (ES) and inhalant siphons (IS), kidney (K), oesophagus (O), stomach (S), structure like-ventricle (SV), and rectum (R), passing through the ventricle (V).

Fig. 4.

(A) A camera lucida drawing of the dorsal aspect of the kidney after the removal of its roof to show the internal septae and chambers; lateral left septum (LLS), lateral right septum (LRS), left chambers (LC), middle septum (MS), and right chambers (RC).

(B) A camera lucida drawing of the ventral view (VV) of the heart and ventricle like structure to show their structures; left auricle (LA), pericardium (P), rectum (R), right auricle (RA), ventricle (V), ventricle like structure (VS).

(C) A camera lucida drawing of the ventral side of the ventricle after the removal of the two auricles illustrating the two auricleo-ventricular valves; the left ones (LVA) and the right (RVA).

(D) A camera lucida drawing of the pedal retractor muscles.

(E) A camera lucida drawing of the posterior pedal retractor muscle (PPRM).

(F) A camera lucida drawing of the anterior pedal retractor muscle (APRM).

(G) A camera lucida drawings of the dorsal and ventral aspects of the posterior adductor muscle (PAM).

(H) A camera lucida drawings of the dorsal and ventral aspects of the anterior adductor muscle (AAM).

EXPLANATION OF PLATES

Pl. 1.

(A) A photomicrograph of *Dosinia radiata* (left side) showing the external features of the shell. (U=Umbo; S=Shell)

(B) A photomicrograph of the dorsal aspects of (A) showing the umbo ligament and lunule (LU).

(C) A photomicrograph of the opened shell valves of *Dosinia radiata* showing the internal surfaces, ligament (L), inner pallial line (IPL) and the pallial sinus (PS).

(D) A photomicrograph of the interior upper part of the right shell valves of *Dosinia radiata* showing the ligament, dental plate and the cardinal teeth (CT).

(E) A photomicrograph of the specimen after removing of the right shell valve, showing the mantle lobe, pallial muscles (PM), pallial sinus (PS), umbo (U) and ligament.

(F) A photomicrograph of the lateral aspect of the mussel after the removal of the right shell valve and the right mantle lobe, showing the general viscera, outer demibranch (OD), inner demibranch (ID), foot (F), exhalant siphon (ES), inhalant siphon (IS) kidney (K) and anterior and posterior adductor muscle (AAM, PAM).

Pl. 2.

(A) A photomicrograph of T. S. through the mantle lobe showing the four terminal mantle folds; outer mantle fold (OF), Middle fold (MMF), proximal inner fold (PF) and destal inner fold (DF).H & E stain. X 31.35.

(B) A photomicrograph of T. S. of the mantle fold showing the collagenous fibers (CF) of the basal lamina and that of the connective tissue core. Masson Trichrome method. X 125.

(C) A photomicrograph of T. S. of the outer middle fold showing the PAS positive contents of the covering epithelium (CE), reticular fibers (RF) of basal lamina and the PAS positive granules (SG) of the

connective tissue core. PAS method. X 125.

(D) A photomicrograph of T. S. of the outer fold showing the mucoids (MU) of the covering epithelium (CE), and diffusing throughout the connective tissue core. Southgat's mucicarmine method. X 200.

Pl. 3.

(A) A photomicrograph of T. S. of the mantle sinus illustrating the bundles of longitudinal muscle fibers (MF). H & E stain. X 31.35.

(B) A photomicrograph of enlarged portion of (A) to show the covering epithelial sheath (E) and the muscle fibers (MF). H & E stain. X 125.

(C) A photomicrograph of L. S. of the shell muscle. H & E stain. (MF= muscle fibers). X 125.

(D) A photomicrograph of T. S. of the shell muscle. (MF= muscle fibers; H & E stain. X 125.

Pl. 4.

(A) A photomicrograph of T. S. of kidney to show its general structures. (KT= kidney tubules; S= kidney stones). H & E stain. X 31.35.

(B) An enlarged portion of (A) showing the fine histology of the kidney. H & E stain. X 500.

(C) A photomicrograph of T. S. of the ventricle (V) penetrated by the rectum (R). H & E stain. X 31.35.

CD) A photomicrograph of T. S. of the structure like ventricle (SV), showing the rectum (R) penetrating it.

Pl. 5.

(A) A photomicrograph of T. S. of an inhalant siphon to show the general structure. (SO= siphonal opening). H & E stain. 31.35 X.

(B) Enlarged portion of (A) showing the mucoid contents (MU). Mucicarmine stain. 500 X.

(C) A photomicrograph of T. S. of exhalant siphon to show the general structure. SO= siphon opening . H & E stain. 31.35 X.

(D) Enlarged portion of (C) to show PAS positive cellular contents and reticular fibers (RF) of the underlying lamina. PAS stain. 500 X.

Pl. 6.

(A) A photomicrograph of T. S. of the foot (F) showing the folded epithelium (FE) of both sides. H & E stain. 31.35 X.

(B) A photomicrograph of an enlarged part of the foot showing the ciliated epithelium (CE), an apical basophilic zone (ABZ) and the diffused collagenous fibers (CF) of the basal lamina and the connective tissue bulk (CT) contains blood vessels (BS). Masson trichrome stain. 125 X.

(C) A photomicrograph of T. S. of an enlarged part of foot showing the PAS positive contents (C) of the covering epithelium, PAS method. 125 X.

(D) A photomicrograph of T. S. of an enlarged part of foot showing the mucoids contents (MU) of the epithelium. Southgat's mucicarmine stain. 200 X.

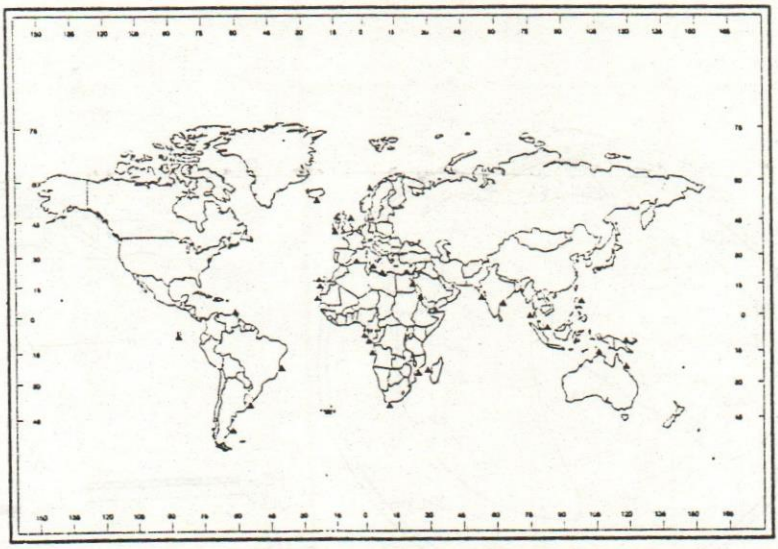


Fig. 1 (A): map showing a wide range of the geographical distribution of the genus *Dosinia* in the world.

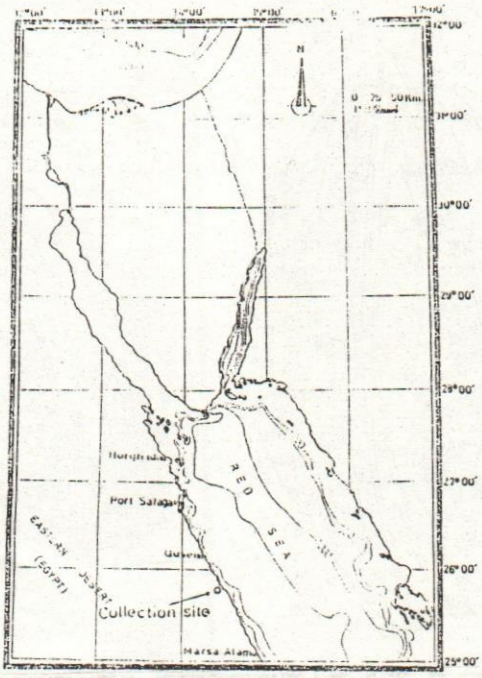
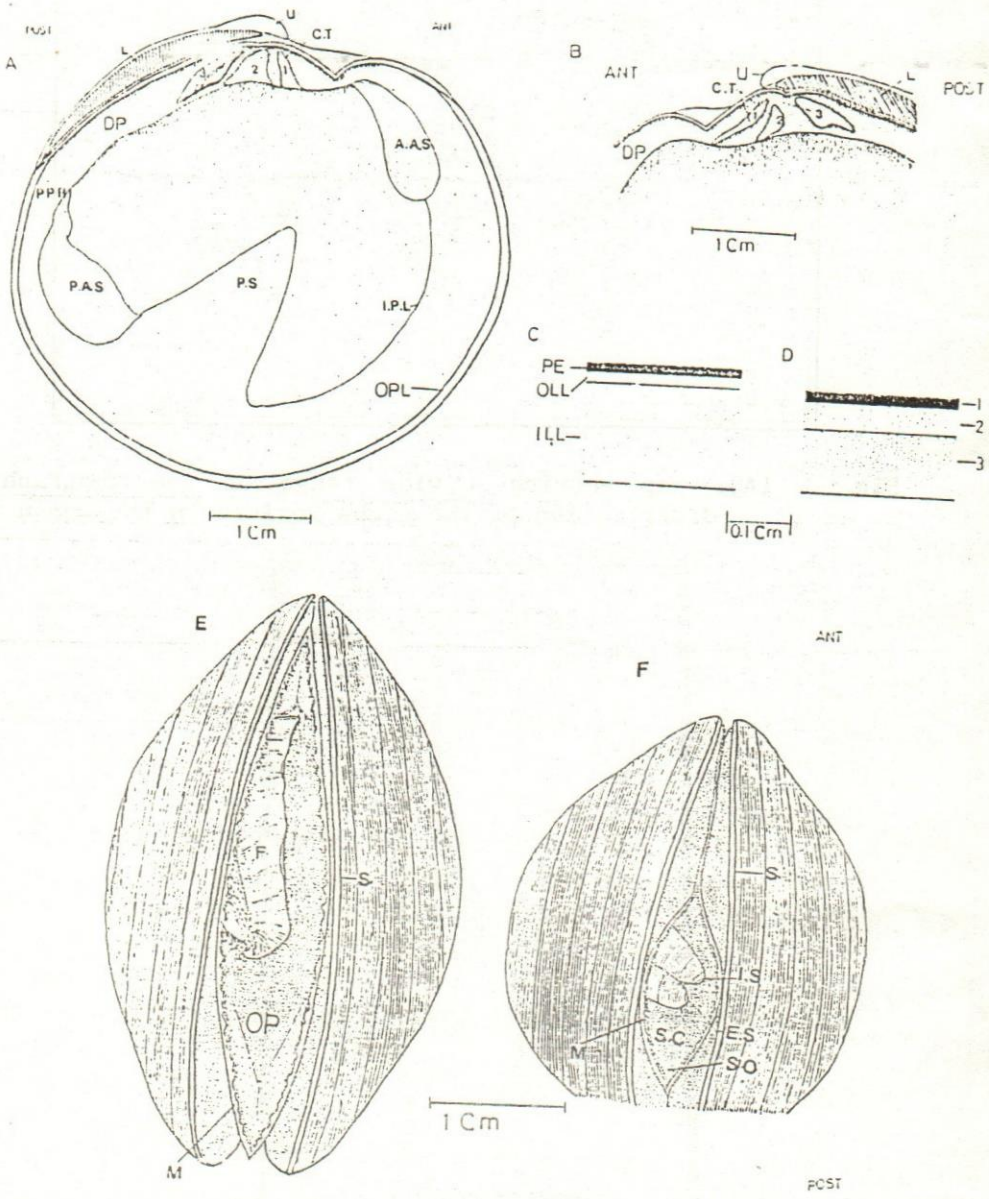


Fig. 1 (B): map of the Red Scá, showing the collection site.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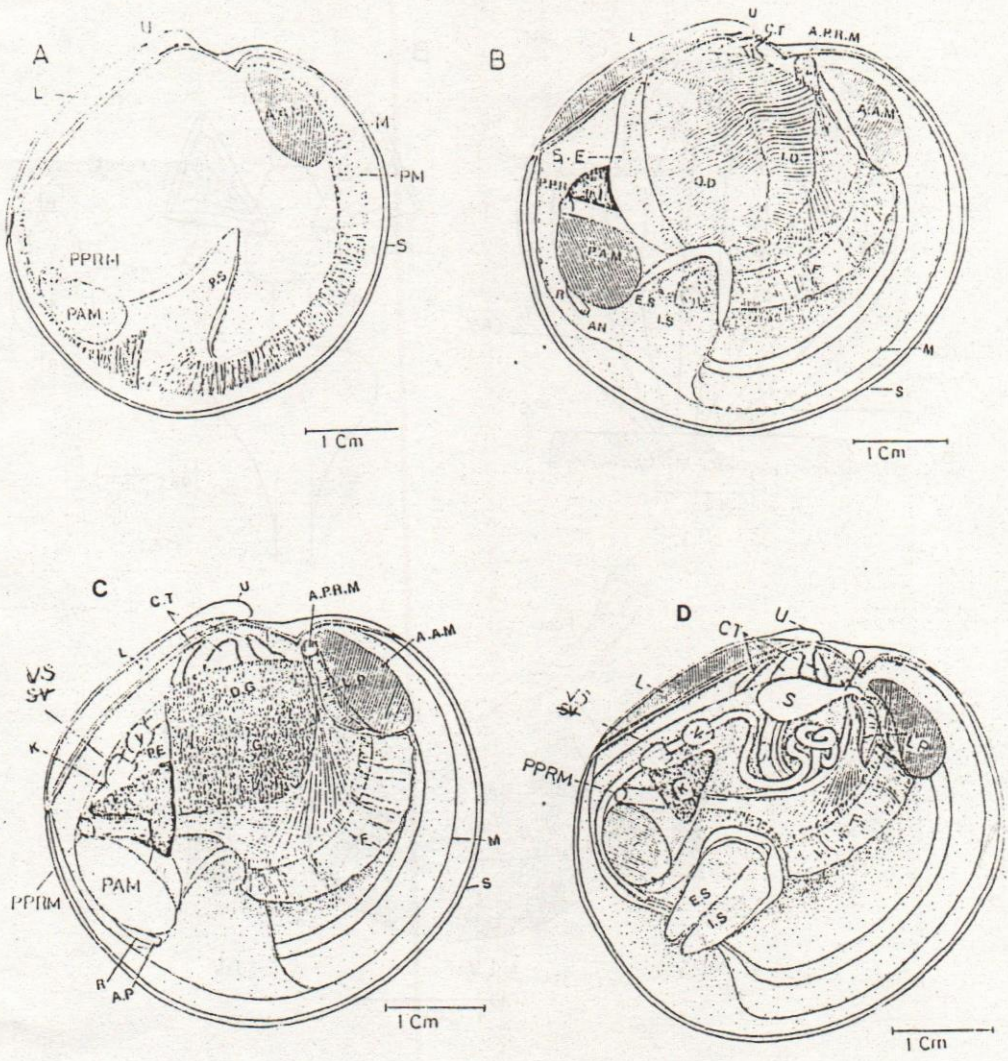
S.C
E.S
S.O
M
POST

Fig. 2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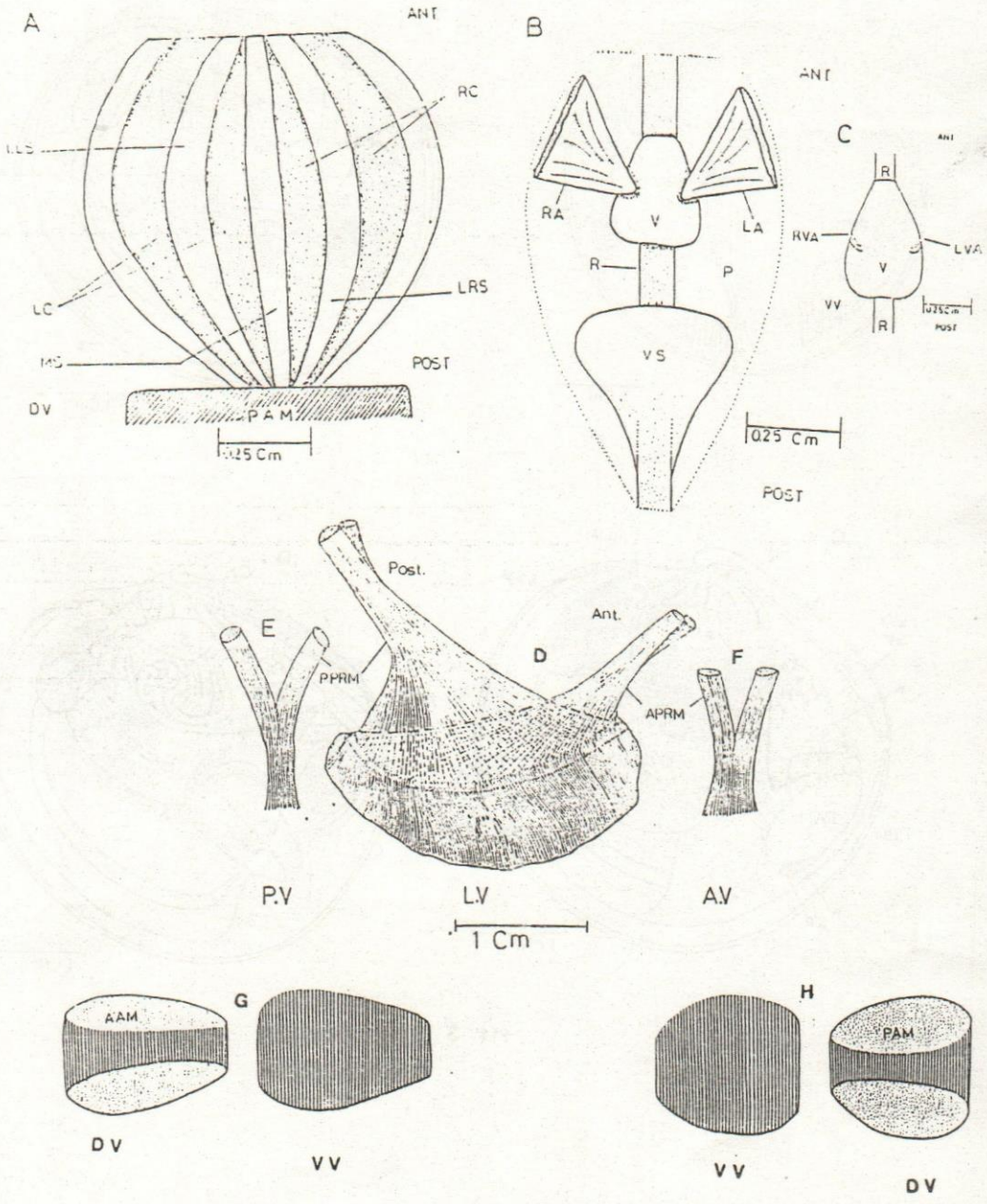
L
A.P.R.M
M
PM
S
PPRM
P.S
PAM
1 Cm
B
U
L
C.T
A.P.R.M
A.A.M
S.E
I.O
Q.D
P.R.M
P.A.M
R
E.S
I.S
AN
M
S
1 Cm
C
C.T
U
A.P.R.M
A.A.M
L
V.S
S.V
Q.G
L.P
K
Y
P.E
F
M
S
PAM
PPRM
R
A.P
1 Cm
D
C.T
U
L
V.S
S.V
S
PPRM
K
E.S
I.S
1 Cm

Fig. 3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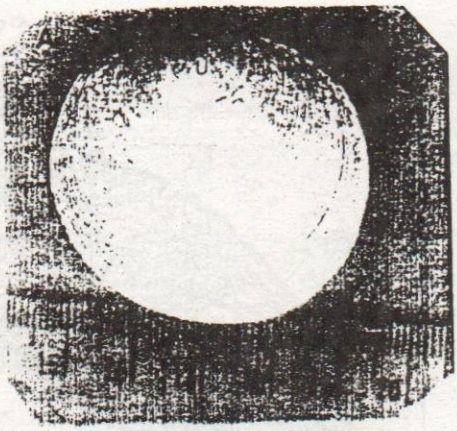
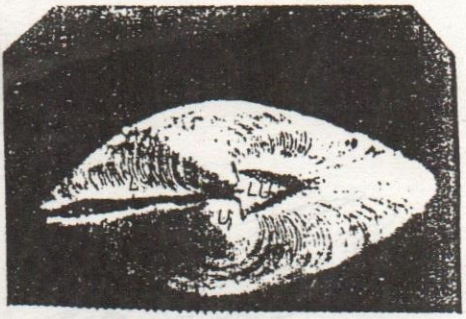
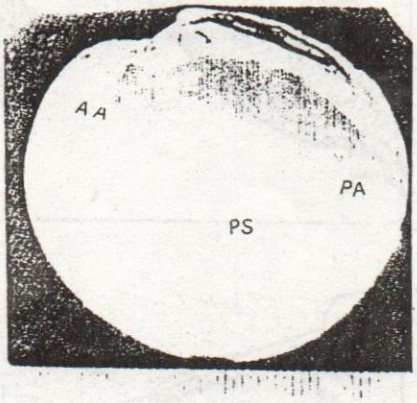
LRS
LC
POST
DV
PAM
0.25 Cm
B
ANT
RA
V
LA
R
P
VS
0.25 Cm
POST
C
ANT
R
RVA
LVA
V
VV
R
POST
Post.
Ant.
E
PPRM
D
APRM
F
P.V
L.V
A.V
1 Cm
AAM
G
DV
VV
H
VV
PAM
DV

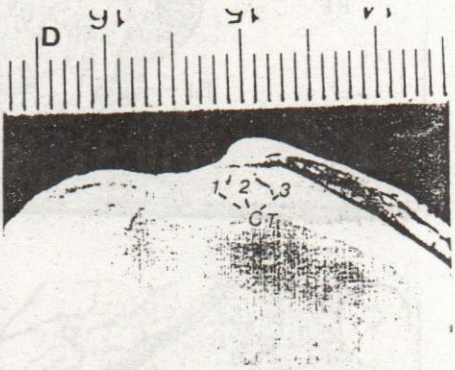
Fig.4

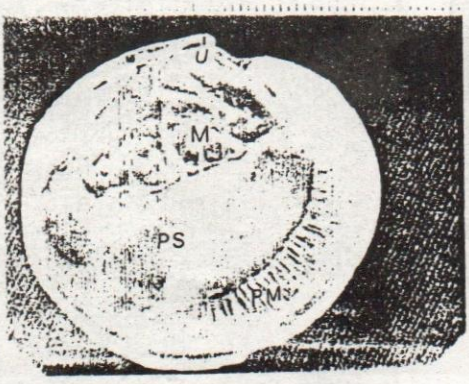
PLATE 1











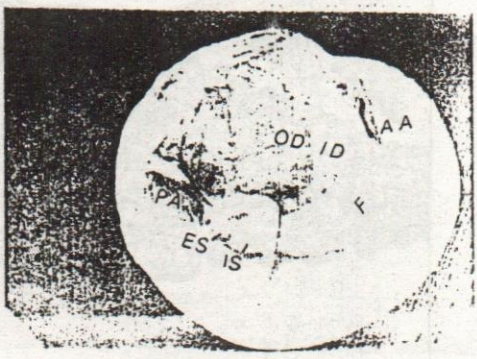


PLATE 2

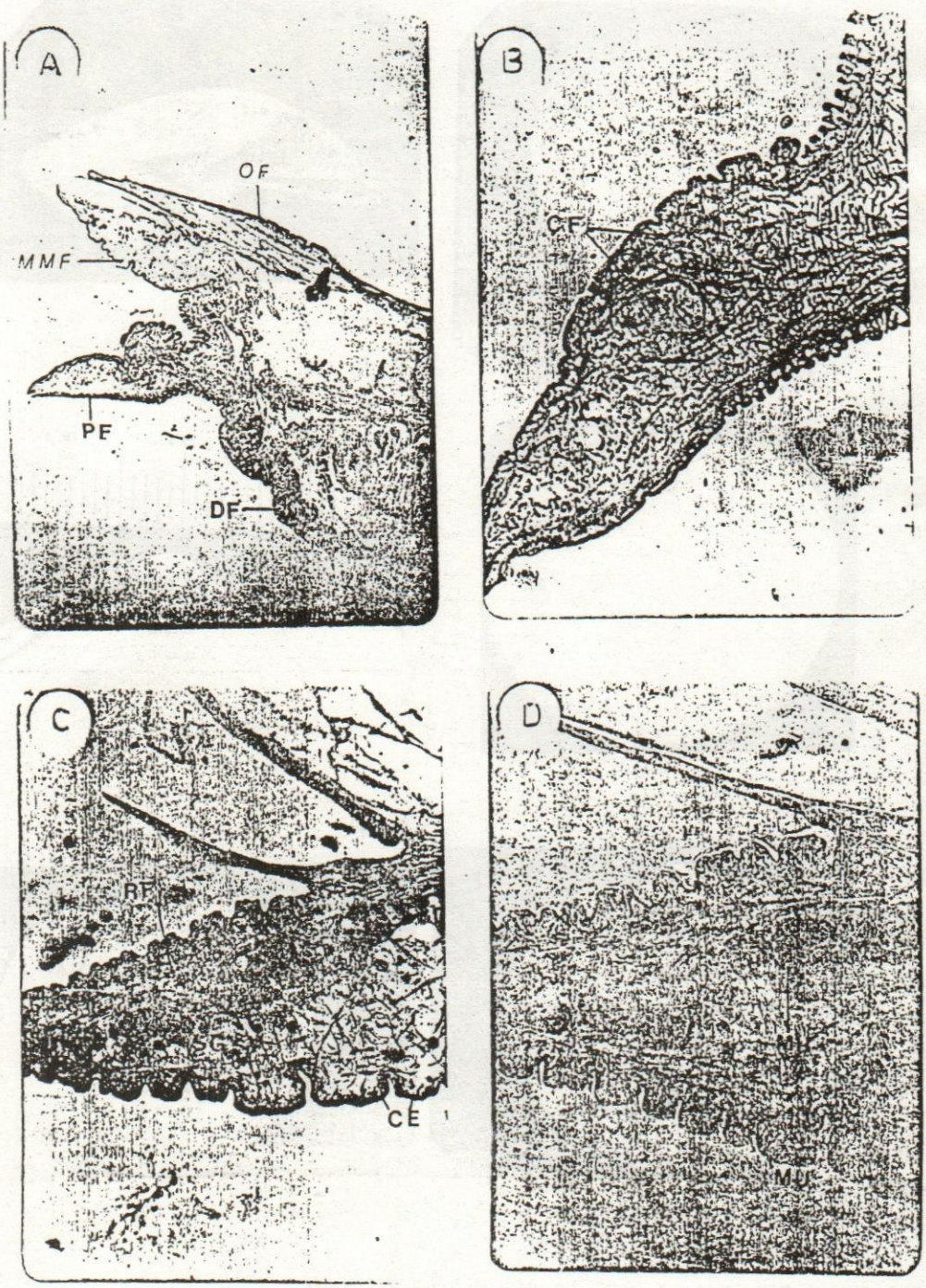


PLATE 3.

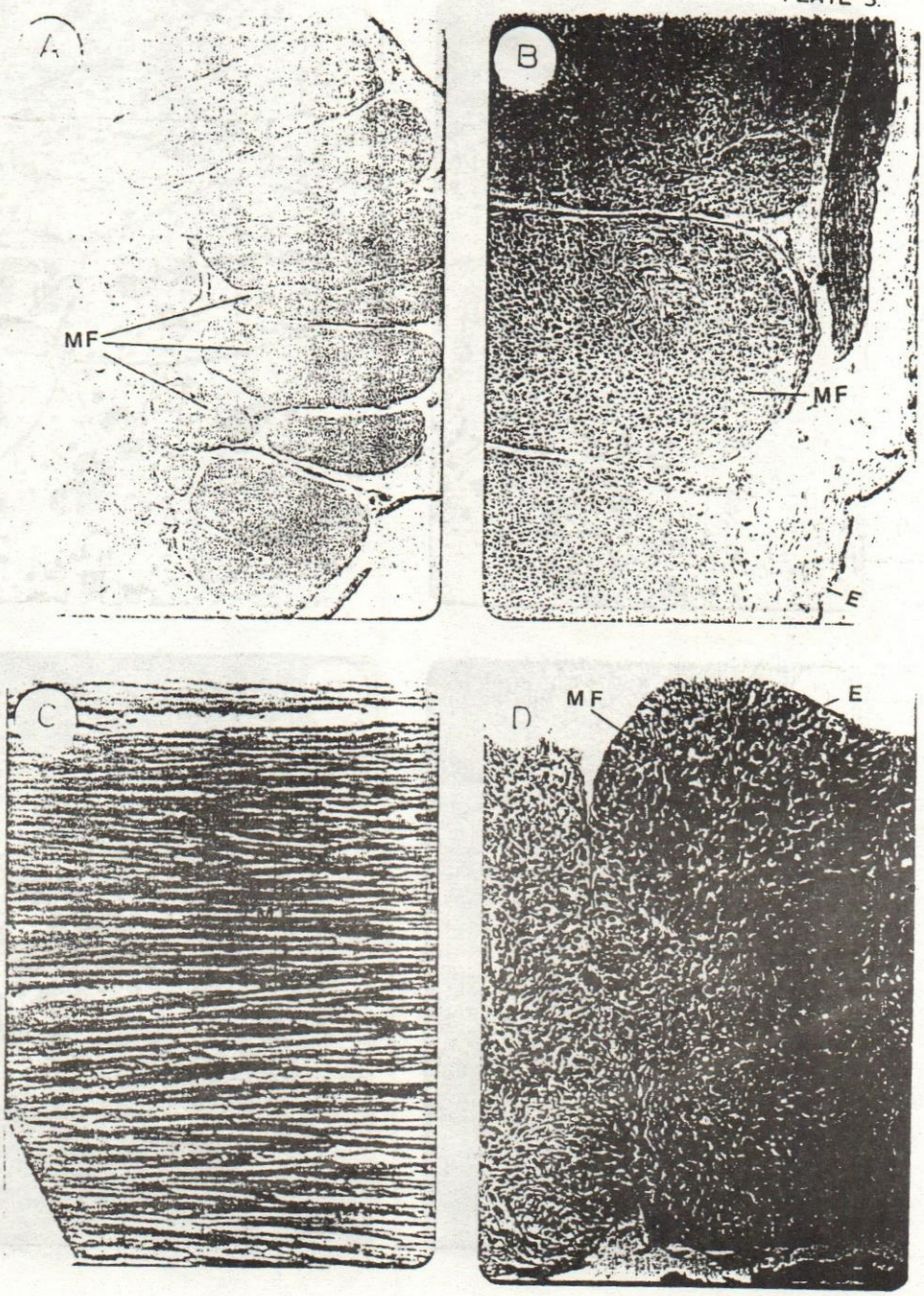


PLATE 4.

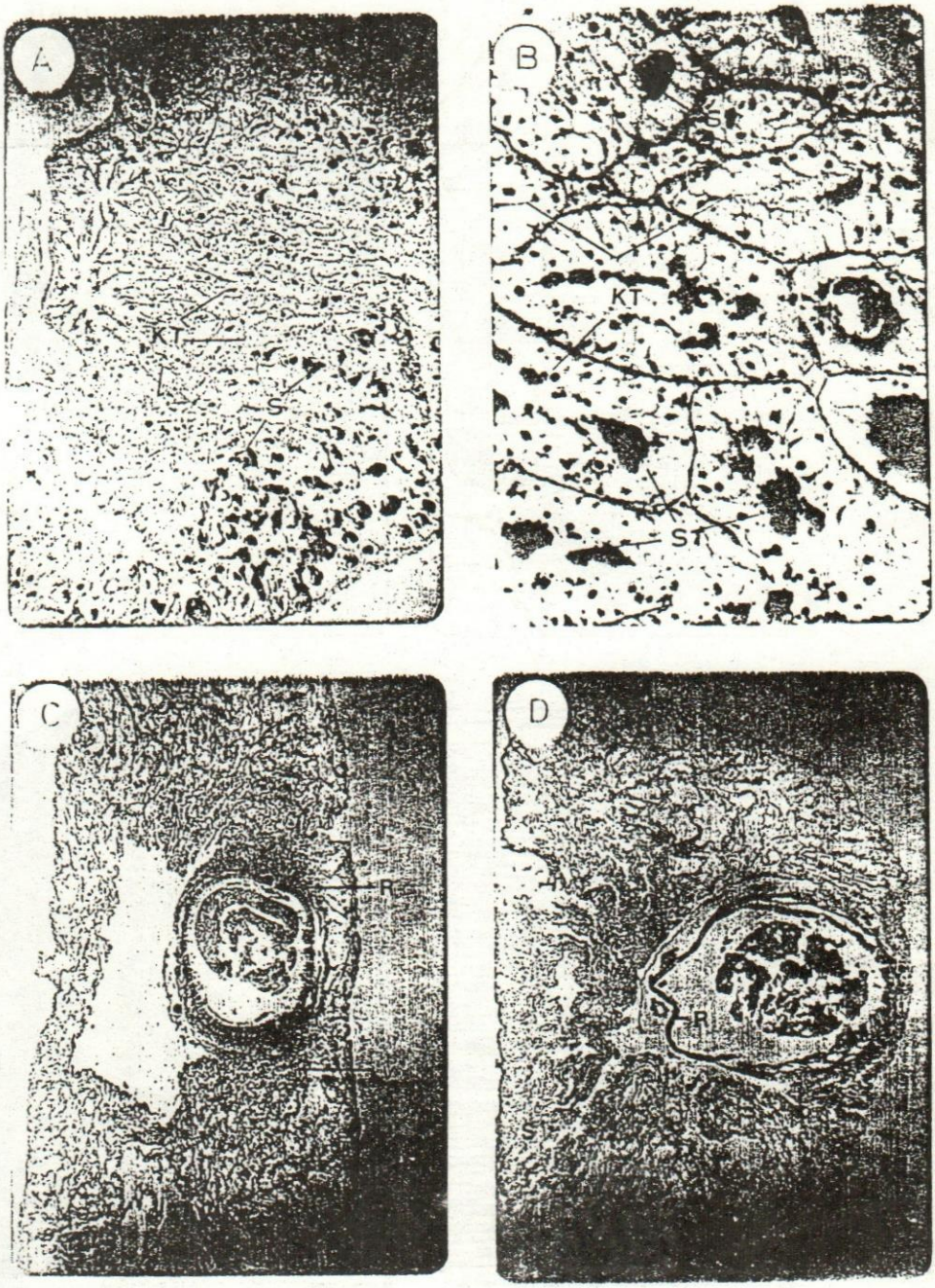


PLATE 5.

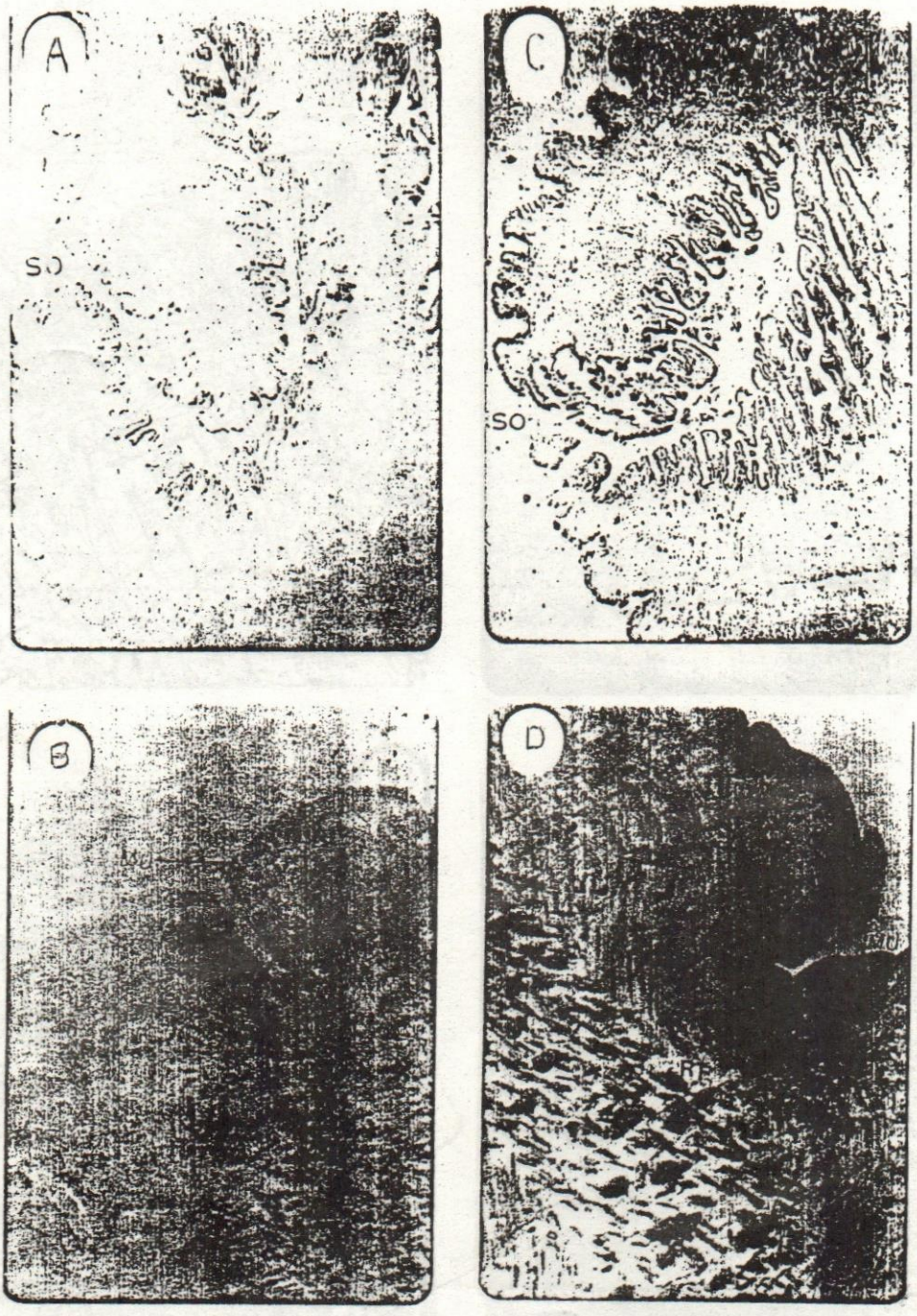


PLATE 6.