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The modern environments of Molluscs in southern Mesopotamia, Iraq: A guide to paleogeographical reconstructions of Quaternary fluvial, palustrine and marine deposits.

Jean-Claude PLAZIAT¹

Woujdan R. YOUNIS²

Abstract: The Quaternary, mainly freshwater sediments of the Lower Mesopotamian plain include a thin transgressive marine unit which extends inland some 250 km from the present coastline, the Hammar Formation. The identity and respective areal extent of continental and transgressive units are based mainly on their molluscan faunas. Those faunas reflect the several environments of the Middle Eastern biogeographic province: fluvial, lacustrine, estuarine and lagoonal. The ecological requirements of the more common subfossil and living species of the malacofauna were studied during a month of field reconnaissance.

The freshwater portion comprises only four bivalve species (*Corbicula*, *Unio*, *Anodonta* and *Pseudodontopsis*). The principal gastropods include *Theodoxus* (*Neritaea*), *Melanopsis*, *Melanoidea*, *Bellamyia*, *Gyraulus*, *Lymnaea* (*Radix*) spp. *Corbicula* characterizes both fluvial channels and lacustrine environments; *Melanopsis*, *Melanoidea*, *Theodoxus* and the Unionaceae prefer shallow, sparsely vegetated, freshwater lakes. The greatest diversity was seen in the slowly flowing water of the channels draining the marshes; small Planorbids are rarely abundant whereas viviparid and lymnaeids may accumulate near the margins of marshes due to floatation during floods.

The brackish water faunas are characterized by *Neritina* (*Dostia*), the potamid *Cerithidea* (*Cerithideopsis*), and *Stenothyra*. The new combination *Theora mesopotamica* (ANNANDALE, 1918) is introduced here as the exact equivalent of *Abra cadabra* EAMES et WILKINS, 1957. The abundance of these species is indicative of a restricted, low energy marine environment, confirmed by great numbers of the foraminiferan *Ammonia* gr. *beccarii* and the ostracod *Cyprideis* gr. *torosa*.

Reworked Hammar Fm marine fossils, first recorded by the ANNANDALE (1918) collection from a lacustrine deposit near Nassiriyah, have been observed in river, marsh and lake sediments too, usually in association with scarce foraminifera. The limited occurrence of these macrofossils (abundant in their life environment) indicates reworking.

Key Words: Iraq; Mesopotamia; Arabian Gulf; Tigris; Euphrates; Shatt al Arab; freshwater; mollusc; brackish water; Holocene; Hammar Formation; ¹⁴C dating; ecology; *Typha* marsh; reed culture.

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Résumé : Les environnements modernes des Mollusques en Mésopotamie méridionale, Irak : Un guide pour les reconstitutions paléogéographiques des dépôts quaternaires fluviaux, palustres et marins.- Les dépôts quaternaires d'eau douce de la plaine de Mésopotamie comportent une mince intercalation marine : la Formation Hammar qui a transgressé d'environ 250 km par rapport au rivage actuel. L'identification et l'extension des unités sédimentaires continentales et marines sont basées essentiellement sur les faunes de mollusques. Ces faunes caractérisent les différents environnements fluviaux, lacustres, estuariens et lagunaires de la province biogéographique du Moyen Orient, très peu étudiés du point de vue écologique. Les conditions de vie des espèces les plus abondantes, vivantes et fossiles, ont été observées durant une mission de reconnaissance, en 1980.

La malacofaune d'eau douce comporte des bivalves peu variés (*Corbicula*, *Unio*, *Anodonta* et *Pseudodontopsis*) et les genres de gastéropodes *Theodoxus* (*Neritaea*), *Melanopsis*, *Melanoidea*, *Bellamyia*, *Gyraulus*, *Lymnaea* (*Radix*) spp. La corbicule caractérise aussi bien les chenaux fluviaux que les environnements lacustres ; les *Melanopsis*, *Melanoidea*, *Theodoxus* et unionidés préfèrent les lacs à végétation clairsemée. La plus grande diversité s'observe dans les chenaux d'eau à faible courant qui drainent les marais ; les petits planorbes sont rarement abondants tandis que les paludines et les limnées peuvent former des accumulations en bordure des marais, par flottation et échouage en période de hautes eaux.

La faune saumâtre est caractérisée par une néritine (*Dostia*), le potamide *Cerithidea* (*Cerithideopsis*) *cingulata* et *Stenothyra*. Nous introduisons la nouvelle combinaison *Theora mesopotamica* (ANNANDALE, 1918) en remplacement de la regrettée *Abra cadabra* de EAMES et WILKINS (1957). L'abondance de ces espèces caractérise un environnement maritime calme et confiné, confirmé par le grand nombre de tests du foraminifère *Ammonia* gr. *beccarii* et de l'ostracode *Cyprideis* gr. *torosa*. Le remaniement de fossiles de la Formation Hammar peut être mis en évidence dans les dépôts lacustres, palustres et fluviaux. Les mollusques saumâtres ont été signalés pour la première fois par ANNANDALE (1918) près de Nassiriyah mais mal interprétés. Leur faible abondance, en mélange avec la malacofaune d'eau douce, caractérise leur remaniement.

Mots-Clefs : Irak ; Mésopotamie ; Golfe Arabique ; Tigre ; Euphrate ; Shatt al Arab ; eau douce ; mollusque ; eau saumâtre ; Holocène ; Formation Hammar ; datation ¹⁴C ; écologie ; marais à *Typha* ; culture des Arabes des marais.

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Foreword

This contribution is based on a 1980 field and laboratory study, organized by B.H. PURSER as a joint research project of the Laboratory of Sedimentary Petrology and Paleontology (Paris-Sud University, Orsay) and the Geological Survey of Iraq (Baghdad). The study was made shortly before the onset of the war that destroyed most of the natural environments of Mesopotamian swamps and lakes (Fig. A), and consequently the amphibious villages of the Arabian Reed Culture (Fig. B). Its findings were presented at the 1987 Kuwait Conference on Quaternary Sediments in the Arabian Gulf and Mesopotamian region, the proceedings of which have never been issued. Consequently, the ecological field data of the Mesopotamian model have not been available, so we offer this revised version of our contribution in the hope of inciting greater interest to the environments of the Mesopotamian plain. The collected samples were studied in 1980 and stored in the collections of Orsay University. However only two subfossil lake samples escaped vandalism in a subsequent reorganization of storage.

Introduction

The Quaternary sediments underlying the alluvial plain of lower Mesopotamia are predominantly fluvial deposits but include a thin Holocene marine unit, the Hammar Formation (HUDSON *et alii*, 1957), that has been reported to extend from Basrah to Najaf, *i.e.* more than 450 km inland from the present mouth of the Shatt al Arab estuary. Study of the paleogeographic evolution of the historic "Mesopotamia" (southern Sumeria) began before the Second World War. Figure 23 in RZÓSKA (1980) reproduces for the first time maps showing these reconstructions as they appeared in the anonymous "Handbook of Iraq and the Persian Gulf" (War office, 1944). Subsequent research on the content and distribution of this marine unit introduced paleontologic studies and elucidated its significance concerning local subsidence and tectonics (HUDSON *et alii*, 1957; EAMES & WILKINS, 1957; MITCHELL, 1958; DANCE & EAMES, 1966; LARSEN & EVANS, 1978; MACFADYEN & VITAFINZI, 1978). The importance of eustasy was emphasized later (POSAMENTIER & VAIL, 1988, Fig. 19). This Late Quaternary marine to lagoonal incursion was the transgressive head of the Arabian-Persian Gulf that attained its highest level during the Holocene Optimum (Fig. 1). The marine strata are interfingered between the fluvial, marsh and lacustrine deposits of the Tigris and Euphrates rivers that progressively built parallel internal deltas NW of their present confluence at Qurna. In a few thousand years the head of the Gulf moved southeastward more than 250 km, replaced

south of Basrah by the Shatt al Arab delta, except in the west where a residual marine channel, the Khor Zubair, may be interpreted as a marginal bay of this delta (Fig. 2). The Shatt al Arab delta is mainly a contribution of the Karun river, for the detritus of its flood stages is added to that of the two major Mesopotamian rivers (PURSER *et alii*, 1982; BALTZER & PURSER, 1990). The excess of Karun alluvium, derived from the northern Zagros mountains, abuts the coarse-grained Wadi al Batin alluvial fan, the detritus of the Arabian shield. Together, they narrowed the depression south of Basrah and contribute to the recent southeastward development of the Shatt al Arab delta.

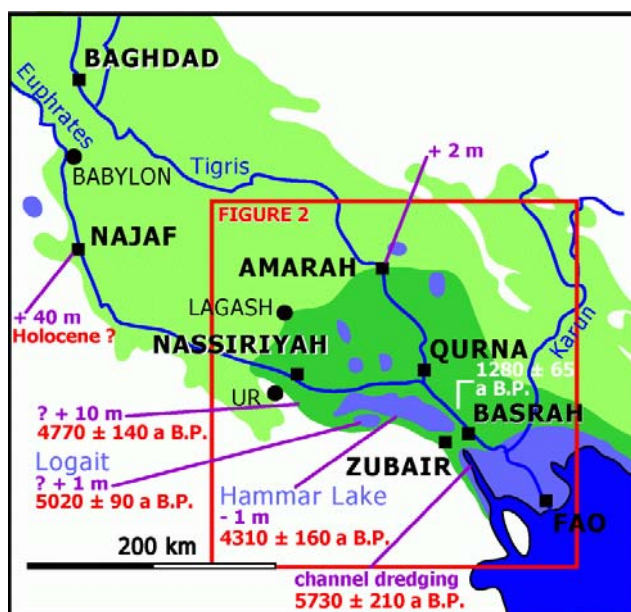


Figure 1: The alluvial plain of Lower Mesopotamia. Location of the principal localities cited. Unpublished dates (^{14}C - Lab. of Hydrology, Orsay) of fossils from the Hammar Fm (dark green).

► Figure A: The freshwater marshes, north of Lake Hammar.

- 1 - The Mesopotamian reed marshes include very large flooded areas covered exclusively by *Typha*, the reed mace (= bulrush).
- 2 - The bulrush is the foundation of a cattle breeding culture; seasonal fires (smoke) are set by the stock-breeding tribes to regenerate fresh green *Typha* leaves.
- 3 - The incipient change in scenery. A network of causeways isolated dried marsh and lake areas (right) from as yet untouched flooded domain. This was a godsend for the working paleoecologist when it was limited in extent (1980), for it helped the study of molluscan distribution within the polder-like units (Fig. C).
- 4 - Cowsheds of *Phragmites* reeds in the *Typha* domain, close to the *Phragmites* marsh (in the distance). Their platforms are piles of compacted mud taken from the adjacent marsh floor; a peripheral depression (cleared) reveals the water level.
- 5 - Cattle herd in the *Typha*. Last year's cat-tails serve as the origin of the growing green shoots that appeared at the end of winter.

Figure A

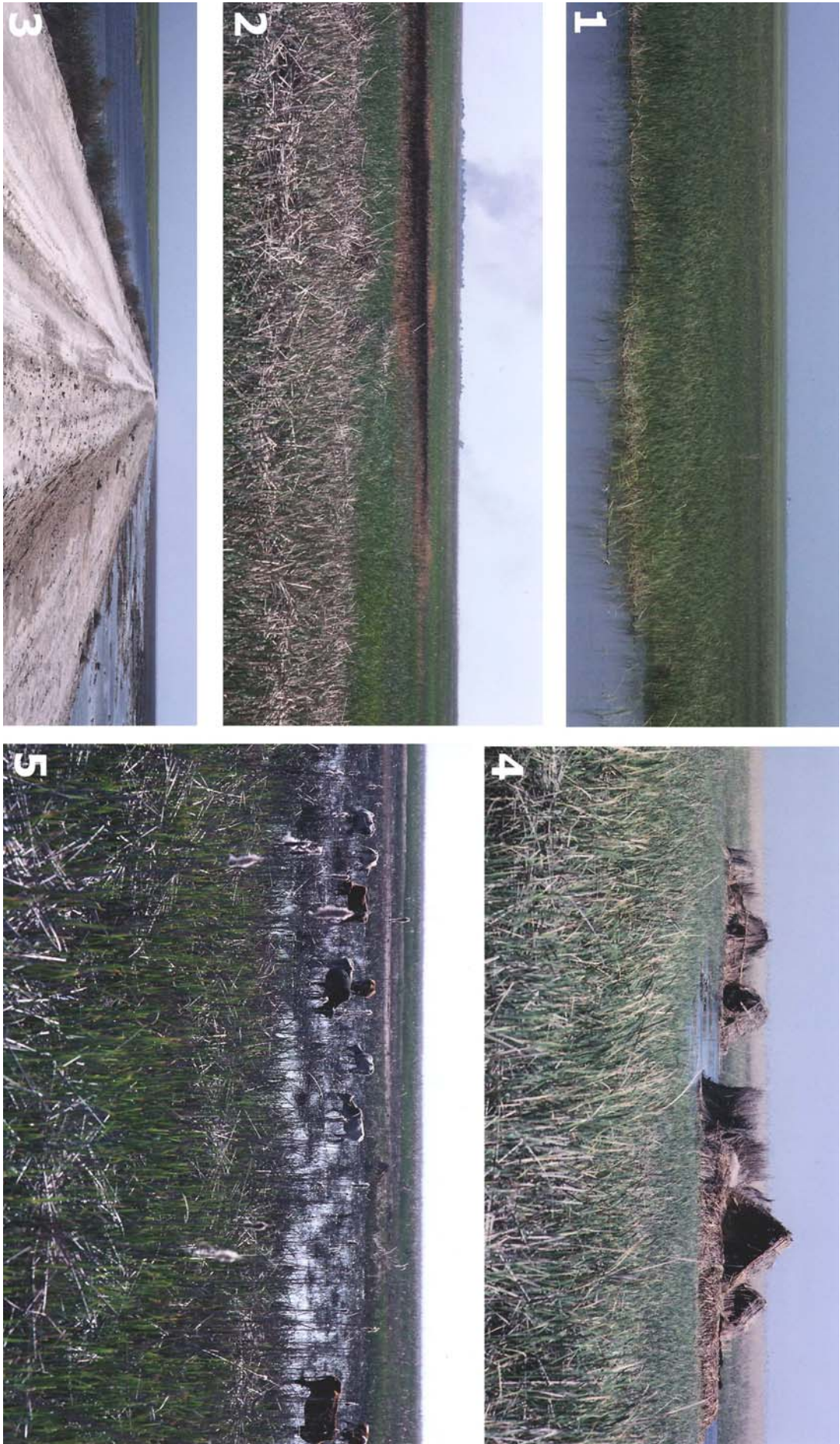




Figure B: The now vanished Lake-and-Reed-Marsh culture of Mesopotamia. Amphibious villages (1-2) were the result of long accommodation to this flooded environment. Each *Phragmites* house is built on an artificial platform, protected by a wave shield (arrow). The skiff in the foreground is filled with *Typha* leaves cut for cattle in the sheds. The mud platform is repeatedly added to compensate for natural subsidence, using sediments dredged during the maintenance of the boat-channels. The punt boat (3) holds one-fourth of a cubic meter of silty alluvium (arrow) for that purpose.

Studies of wells, pits and outcrops of the Hammar Formation show that its upper surface has been affected by neotectonic deformation ranging from -2 to +40 m. The main uplift has occurred on the NW margin of the basin (at Najaf, cf. MACFADYEN & VITA-FINZI, 1978). As a result of this deformation, marine and estuarine fossils have been found reworked in deposits dominated by modern freshwater organisms.

These puzzling faunal assemblages demonstrate the possible influence of early reworking, a phenomenon which may help in elucidating difficult paleogeographic problems such as those of the Eastern Mediterranean Messinian (cf. ORSZAG-SPERBER *et alii*, 2000).

Accordingly, the interpretation of paleoenvironments merits a discussion based mainly on their molluscan faunas. The ecology of the most common living molluscs was documented during a one month field reconnaissance (in March 1980), carried out in collaboration with the Geological Survey of Iraq and completed in France by the study of sedimentary and biological samples. Only a part of the findings have been published by PURSER *et alii* (1982), PLAZIAT (1987) and BALTZER & PURSER (1990).

Climate and hydrology (data from PURSER *et alii*, 1982 and AL AZZAWI, 1986)

The lower Mesopotamian plain, north of 30°N, is in the submediterranean (subtropical) belt, with a local arid character (60-170 mm.yr⁻¹ rainfall) counterbalanced by the fluvial freshwater input from temperate mountains, via the Tigris and Euphrates rivers, both originating in the Kurdish portion of Turkey. Evaporation fluctuates from 50 to 250/600 mm a month (January and July means), highest in July heat (31-35°C, up to 50°C) but is still significant in winter (10-12°C, January mean) because of the strong NW to SE prevailing winds (Shamal). The marsh and lake area is affected not only by contrasting local climatic conditions (temperature, hygrometry) but also by marked fluctuations in the delivery of exotic freshwater.

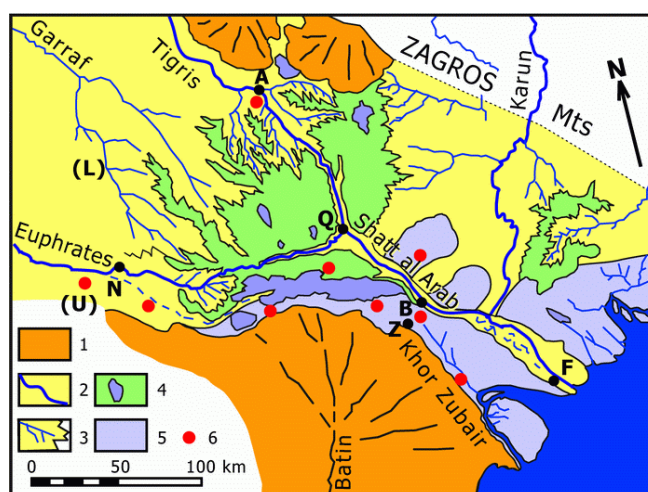


Figure 2: Major morpho-sedimentary units in Lower Mesopotamia (after PURSER *et alii*, 1982, modified). 1- Alluvial fans, 2- Fluvial channel and levees, 3- Lacustrine delta, 4- Marsh and lake, 5- Sabkha (marine and continental), 6- Hammar Formation fossils (late Quaternary transgression). A: Amarah, B: Basrah, F: Fao, N: Nassiriyah, Q: Qurna, Z: Zubair, (L): Lagash, U: Ur.

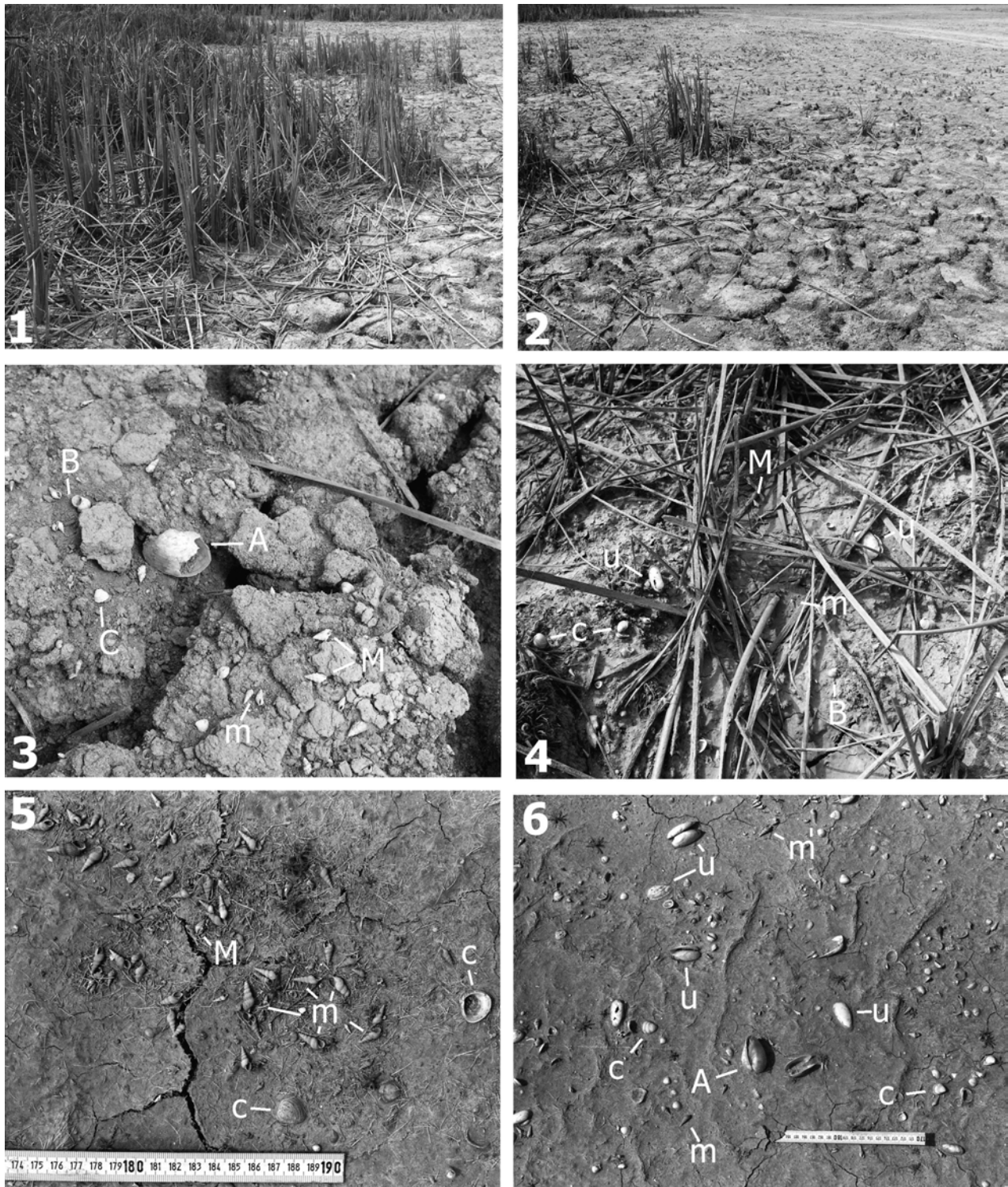


Figure C: The dried bottom of the *Typha* marshland and adjacent lake revealed by a polder-like development. This dammed area (Fig. A.3), suddenly cut off from natural flooding, has not been subject to cattle tramping and grazing. The well preserved freshwater malacofauna includes the viviparid *Bellamyia* (B), *Melanopsis* (M), *Corbicula* (C), the unionids *Anodonta* (A) and *Unio* (U) and *Melanoides* (m). There is a minor difference between marsh and lake molluscan assemblages: *Bellamyia* and *Melanopsis* are typical of the vegetal substrates of the marsh area and *Melanoides* is more abundant on lake floors.

Prior to the end of the XXth century the discharge rate of the Tigris ranged from 3000 m³.sec⁻¹ to less than 500 m³.sec⁻¹ while that of the Euphrates ranged from 2000 m³.sec⁻¹ to less than 250 m³.sec⁻¹, thus accounting for the variations in T.D.S. (total dissolved salt) of the

rivers' waters (0.4 to 0.75‰ or g.l⁻¹). The origin of these rivers in mountains of the temperate zone accounts for the fact that their high water stage is restricted to the February-June period during which rain is abundant and snow melts. This is reflected by variation in the

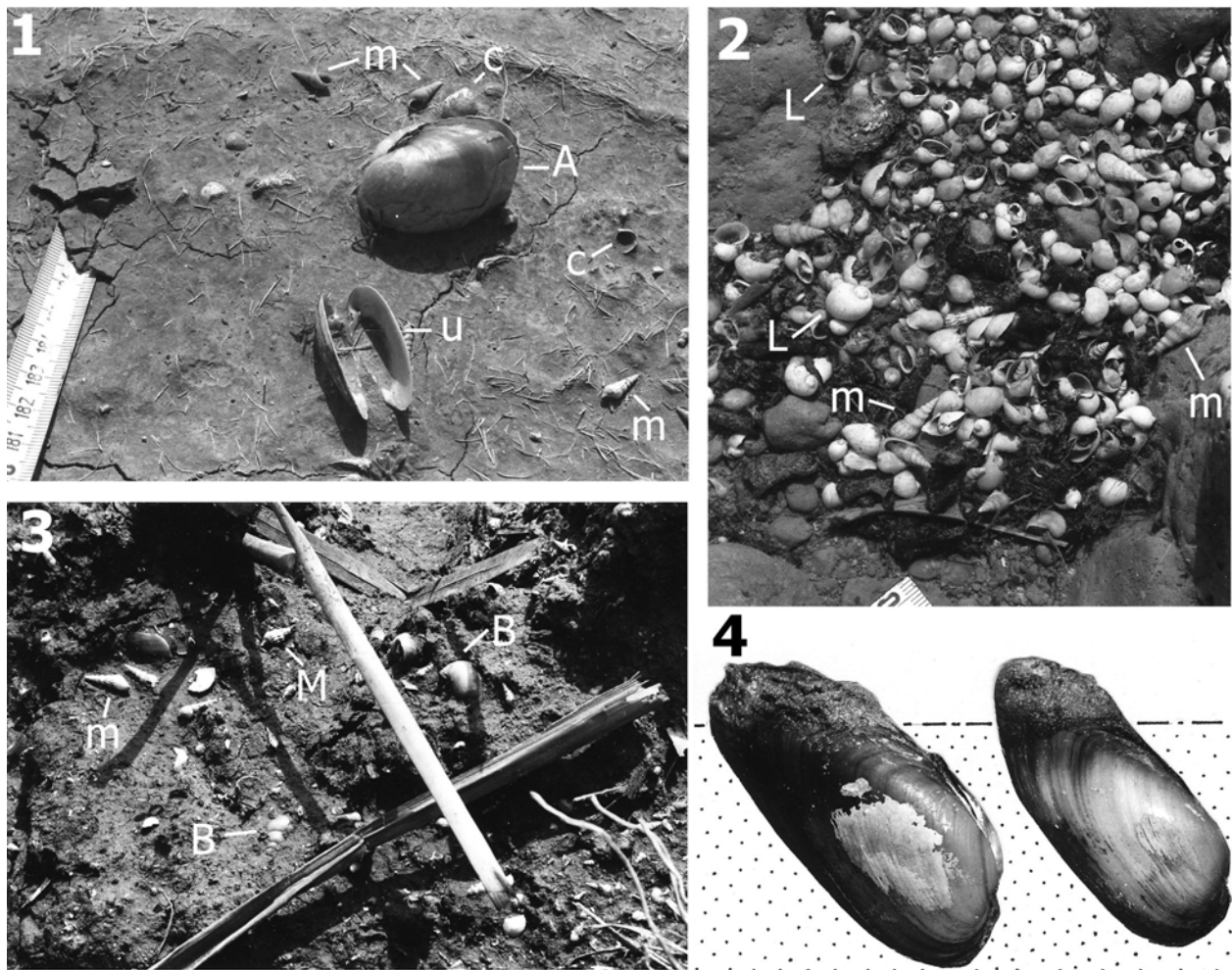


Figure D: Contrasting molluscan assemblages of the freshwater subenvironments.
 1 - Lacustrine mud bottom with an *Anodonta* (A) in life position, a bivalved *Unio* (U), and sparse *Melanoides* (m) and *Corbicula* (C).
 2 - A high energy shoreline accumulation of floated snails: *Lymnaea* (L) and *Melanoides* (m).
 3 - The calm *Typha* marsh bottom includes *Bellamya* (B), *Melanopsis* (M) and *Melanoides* (m).
 4 - *Unio tigridis* taken from the bottom of a marsh channel with active currents. The buried anterior part of the shell is free of encrusting algae.

salinity of the Shatt al Arab estuary: at Abadan salinity remains below 1‰ from February to July while attaining 8‰ in November and December. In accord with these factors marshes and associated lakes had surface water salinities ranging around 1 to 2‰ in March 1980 (PURSER *et alii*, 1982). A large part of this low area is subject to seasonal flooding and drying; the peripheral subemergent to emergent *Typha* swamps are grazed by buffalo (Fig. A). Permanent lakes are located not only in the interior of the extensive marshes but also in the barren sabkhas that fringe the southern desert. The high salt content of these southernmost lakes (15/20‰ TDS in March) precludes the existence of a molluscan biota, whereas the extensive palustrine and lacustrine areas harbour the malacofauna reported below.

The freshwater fauna

The taxonomy of molluscan species and their ecological requirements needs reexamination because these subjects have been neglected for

a considerable period and sometimes misinterpreted (ANNANDALE, 1918). The freshwater basin of Lower Mesopotamia includes an extensive association of reeds (*Phragmites* and *Typha*) in the marshlands, controlled by the existence of a ground-water table that is in equilibrium with the flowing rivers. These rivers are almost completely isolated from the adjacent marshes by alluvial levees of several types. The lotic waters of isolated lakes bounded by a reed filter are typical shallow interdistributary (holomictic) lakes. They are characterized by unmixed carbonate sedimentation (PURSER *et alii*, 1982; FREYET & PLAZIAT, 1982).

The Mesopotamian freshwater malacofauna was first described by MOUSSON (1874). He described, but did not illustrate the fauna collected by SCHLAEFLI before 1860. In fact, the majority of the species he considered to be new is synonymous with species described previously. Subsequent studies of them and their ecology included misinterpretations (ANNANDALE, 1918) so their ecological

requirements stand in need of reexamination. Their taxonomic revision was done to some degree, largely from a systematic viewpoint, by ANNANDALE (1918, 1920), ANNANDALE & PRASHAD (1919), GERMAIN (1924) and HAAS (1969). New collections by SOYER (1961) and the field survey by our group have made possible a general review of the more important species.

Bivalve molluscs generally dominate subaquatic environments.

Corbicula fluminalis MÜLLER (Pl. 3, fig. 19-29) is a highly variable species ranging from a very thick, triangular morph (*C. cor* LAMARCK), to a flatter, elongate morph (*C. tigridis* MOUSSON). The ratio of height (umbo-ventral) to length (antero-posterior) dimensions may serve to characterize these morphotypes. It fluctuates between the median values of $h/l = 1$ (high morphotype) and $h/l = 0.875$ (elongate morphotype). Their respective distributions do not reflect their environments during life: the elongate morph occurs and may dominate in all of them: lakes, marshes, and the rapidly flowing Tigris. Neither is it characteristic of any one drainage system. The elongate morph represents from 30 to 100% of the *Corbicula* shells in the Tigris channel, versus 13 to 17% in the Euphrates channel, but it dominates in the Euphrates-associated lakes and swamps (up to 100% of *Corbicula* shells). Dominance of this genus (up to 100% of the assemblage) locally characterizes fluviatile channel environments for both living and empty shells are buried in the fine sands and muds of this milieu. It is also abundant in the bottom muds of many lakes and marsh channels but there it is associated with a more varied fauna, enriched by Unionids and gastropods (Pl. 1, fig. 2-3 & 6).

The Unionids (Pl. 2) were revised and reclassified by HAAS (1969) in a review on a worldwide scale. They are assigned to three genera. *Unio tigridis* BOURGUIGNAT, the most common species, has a solid elongate shell buried obliquely in the mud, its posterior end projecting from the bottom in lake and marsh channels (Fig. C.4, C.6, and D.4). *Pseudodontopsis euphraticus* (BOURGUIGNAT) is a large and solid rhomboidal flat shell. It burrows in the bottom muds of lakes and marshes (Pl. 1, fig. 6). *Anodonta (Anodonta) vescoiana* BOURGUIGNAT is the rarest and has a large, thin inflated shell. It is indicative of the quietest lacustrine environments (Fig. C.3, C.6, and D.1). The large size and post-mortem accumulation (lag deposit) of the shells of Unionacea may cause an overestimation of their number in some marsh channels even though their preferred environments are the quiet (lotic) lake and the mud bottoms of *Typha* marshes.

The thick-shelled *Corbicula*, *Unio* and *Pseudodontopsis* as well as the thinner *Anodonta* shells are not often transported far from their

habitat in life. Only high-energy lake shores and river banks may harbor a few displaced valves of *Corbicula* (Pl. 1, fig. 5).

Gastropods are more diversified. They include 7 well-represented species, and a few rarer forms.

Theodoxus (Neritaea) jordani (SOWERBY) (Pl. 4, fig. 11-20). The more or less pronounced degree of transverse constriction on the last whorl of this species gave rise to the naming of three varieties (PRASHAD, 1921, Fig. 1). The species is exceptionally widespread (lakes, marsh channels, fluviatile channels, and estuary). The other Mesopotamian *Neritaea* species retained by PRASHAD: *T. mesopotamicus*, *T. euphraticus* (MOUSSON) and *T. maccrui* (BOURGUIGNAT) are also varieties or morphs (cf. TCHERNOV, 1975).

Melanopsis (Melanopsis) praemorsum (LINNAEUS) (Pl. 4, fig. 29-36) is the name currently given to the diverse nodular, costulate or smooth morphs of North African and Middle Eastern *Melanopsis* (TCHERNOV, 1975; BROWN, 1980; VAN DAMME, 1984). The countless species and varieties attributed to the *Melanopsis* subgenus (or to *Canthidomus* for the costulate morphs) are now considered as a single polymorphic species. It too is ubiquitous, living in lakes and inundated marshes (Fig. C.5 and D.3) (mainly on subaquatic plants) or on the mud or gravel intertidal shores of estuaries (Pl. 1, fig. 1). The nodular morphology is more common in freshwater environments and the smoother form (Pl. 4, fig. 32) appears to be more abundant in estuarine waters.

Melanooides tuberculata (MÜLLER) (Fig. C; Pl. 4, fig. 7-10) is an ubiquitous (African and Euro-Asiatic), euryhaline species generally associated with environments of low salinity (0.2-3‰) (Rosso, 1983) where it may predominate, but it tolerates salinities of up to 23‰. It dwells on subaquatic soft bottoms, often concealed in the sediment where its sinuous track is a characteristic token of its presence in freshwater lakes (Fig. C.5). Empty shells float easily and consequently accumulate on the shores of lakes (Fig. D.2; Pl. 1, fig. 7).

Bellamyia bengalensis (LAMARCK) (Pl. 3, fig. 13-18) is a large viviparid snail, living in quiet fresh water. As it was not recorded by MOUSSON (1874), ANNANDALE (1818) and ANNANDALE & SEWELL (1921), SOYER (1961) considered it to be a recent immigrant. It lives on the bottom muds of ponds, marshes and marsh channels (Fig. D.3) but during flood high waters, the empty shells float and are stranded up to the edge of peripheral emergent reliefs in marsh areas, thus delineating high water marks. It is also present in estuarine shore deposits (Pl. 1, fig. 5-6).

The small Planorbs - *Gyraulus convexiusculus* (MOUSSON), *G. albus* (MÜLLER)

and *G. intermixtus* (MOUSSON) (Pl. 3, fig. 9-12) - commonly are not very abundant and are generally in association with the most diverse of the freshwater assemblages. Their usual habitat is the subaqueous portion of the rooted vegetation of lakes and swamps.

Lymnaea (Radix) gr. auricularia LINNAEUS (Pl. 3, fig. 1-8) has been identified under the specific names *tenera* PARREYSS, *euphratica* MOUSSON, *canalifera* MOUSSON (in Mesopotamia) and *lagotis* SCHRANK (in India, ANNANDALE & RAO, 1925). Probably all are polymorphs of *L. (R.) auricularia*. This species is mainly lacustrine and palustrine, the empty shells commonly float and are stranded along the shores (Fig. D.2; Pl. 1, fig. 7).

The Hydrobids are neither diverse nor abundant. PRASHAD (1921) recorded the Pomatopsidae *Tricula palmyrae* (DAUTZENBERG), the Bithyniidae *Bithynia badiella* PARREYSS and the Hydrobiidae *Amnicola (Alocinna) ejecta* (MOUSSON). These shells are uncommon (< 1%) and in freshwater assemblages are locally rarer than their opercula. We also collected a *Valvata* sp. (rare) and a more common Ancyliidae in flowing fluvial and marsh channels. *Bulinus contortus* was not seen in 1980, although it was figured by ANNANDALE (1918) and recorded by MOUSSON (1874).

Shell assemblages in the marsh-channels (Pl. 1, fig. 4), with active current systems (PURSER *et alii*, 1982) are significantly more diverse and abundant than those of quiet-water environments: the high concentration of living and empty shells on their floors results probably from the combination of a high rate of production, the winnowing of fine sediment and some transport from adjacent quieter environments (*Bellamya*, Pulmonates).

The brackish water fauna

The annual flood, coincident with the beginning of warm weather, tends to limit the increase in salinity caused by evaporation. Thus, the estuarine fauna of the Shatt al Arab consists mainly of freshwater molluscs, except near the mouth: at Fao the salinity attained 2‰ in March 1980. On the other hand, certain of the previously reviewed freshwater species are euryhaline and can tolerate salinities of more than 2‰ during both winter and summer reductions in the delivery of fresh water. This is true in particular of *Melanopsis* and *Melanoides* spp. They can live and even predominate in most of the estuary. Only at its mouth does the malacofauna change with the introduction of the genera *Neritina (Dostia)* and *Cerithidea (Cerithideopsisilla)*.

Neritina (Dostia) schlaeflii MOUSSON (Pl. 4, fig. 21-29). This *Nerita*-like *Neritina* is closely related to *N. (D.) violacea (= crepidularia)* but PRASHAD (1921) considered it to be a valid

species. It forages in the muddy intertidal zone near Fao. It was not recorded in the buried marine Hammar Formation but we collected it in a near surface fossil assemblage, N of Basrah (Pl. 4, fig. 27), thus indicating that it was present relatively early.

Cerithidea (Cerithideopsisilla) cingulata (GMELIN) (Pl. 4, fig. 1-5). Until the mid XXth century, this species was erroneously referred to *Potamides* or *Tympanotonus fluviatilis*. In the Hammar Formation it is represented by a dwarf morph, less than 2.5 cm in length, as are the living specimens now restricted to the Fao area. During the Holocene its range extended northwestward as far as Nassiriyah. ANNANDALE (1918) supposed that it lived there in slightly saline, lacustrine waters. Later work showed that its range was even more extensive: up to the vicinity of Ur (SOYER, 1960) and northward to Amarah (MACFADYEN & VITA-FINZI, 1978). We collected great quantities of this species in fossil shoreline accumulations (beach-rocks), between Nassiriyah and south of Lake Logait where the deposits of the Holocene transgression crop out. This intertidal potamid is well known around the Gulf (Iran, Arabian

► **Plate 1:** Living environment and accumulation of the freshwater and brackish (low salinity) molluscs of Lower Mesopotamia.

Figure 1 - *Melanopsis praemorsum* crawling on a tidal channel bank of the Shatt al Arab delta. Salinity is below 3‰. The extended snout and tentacles (arrow) show this activity to be subaerial although the species is more animated while submerged, particularly on lake vegetation.

Figure 2 - *Corbicula fluminalis* in living position (semi-buried) in a lacustrine, mud bottom scattered with *Melanopsis* and *Melanoides*. The disassociation of the shells after death may have been caused by rain or by birds.

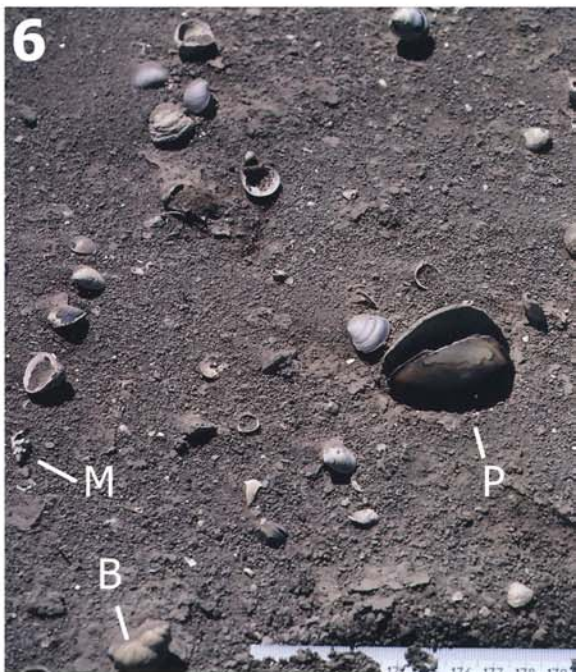
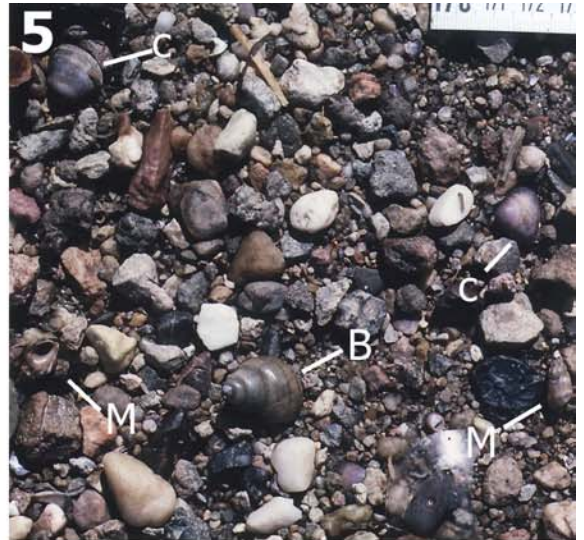
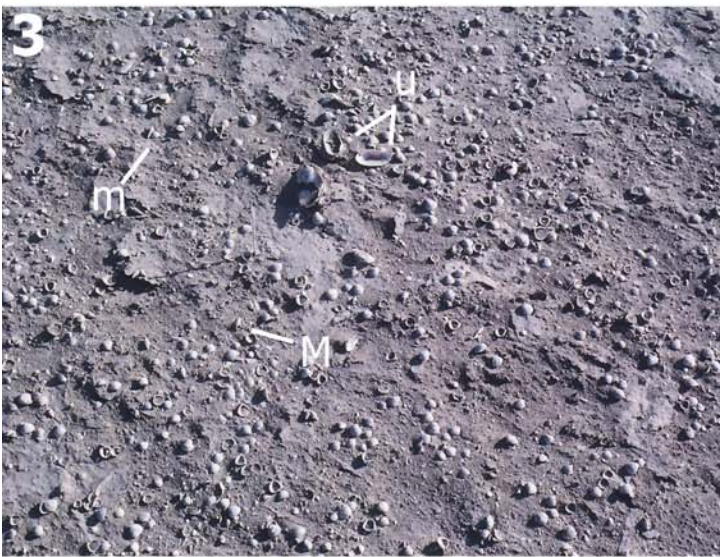
Figure 3 - Dried lake floor preserved by a polder enclosure. *Corbicula* dominated the association that includes only a few (but conspicuous) *Unio* (U) and smaller *Melanoides* (m) and *Melanopsis* (M).

Figure 4 - Underwater photo of the bottom of a marsh channel. The current winnowing reveals accumulation of empty shells and the posterior end of living (buried) *Unio*.

Figure 5 - Shoreline gravel with displaced shells, Shatt al Arab estuary: floated *Bellamya* (B) and bottom traction (current, waves) displaced heavier shells (*Corbicula* - C - and *Melanopsis* - M). They illustrate a high-energy symmigy (mixture).

Figure 6 - Mud lake floor (polder) with *in situ Pseudodontopsis* (P - in living position), slightly moved *Corbicula* valves, a corroded *Melanopsis* (M) (reworked ?) and a possibly floated *Bellamya* (B). This assemblage does not depict incontestably the association in life, for it may include contributions from adjacent environments.

Figure 7 - Floated assemblage at a lake shoreline. Apart from marsh derived plants, the dominant *Melanoides* is associated with *Lymnaea* (L) and *Melanopsis* (M). Corrosion and breakage are most evident in *Melanoides* shells possibly indicating that some of them are redeposited, for the low pH of the sediments hinders fossilization in marsh and lake deposits.



peninsula) as a marine species, tolerating high salinities (40-50‰ metahaline waters). However its extreme euryhalinity enables it to survive in quiet waters below 1.5‰ (PLAZIAT, 1989) if these waters are directly connected with the sea (estuarine mud-flats).

Potamides conicus (BLAINVILLE) appears to be absent on Iraqi shores although abundant on the Arabian coasts (NE Saudi Arabia, Trucial coast, Oman), usually living in the intertidal zone somewhat closer to shore than the sympatric *Cerithidea cingulata*. Thus, it tolerates intense stresses but seems to be better adapted to high salinities than to oligo- to mesohaline waters (PLAZIAT, 1989, 1993). We did not collect it in the Hammar Formation, but a slender morph of *Cerithidea cingulata* like the one living in the lagoonal environment of Khor al Hajar, Oman could be confused with it. During late Holocene times *P. conicus* was abundant on Kuwaiti shores (pers. obs. and unpublished post-Holocene Optimum dates) and therefore seems to have disappeared only recently from the head of the Gulf.

Stenothyra iraqensis DANCE et EAMES (1966) is a small hydrobid species of the Stenothyridae family described from the Hammar Formation at Amarah. This genus is easily identified by its aperture smaller than the preceding whorl. We collected it from that shallow marine unit (borehole of Lake Logait) and from partly reworked assemblages supposedly derived from the same formation (N of Lake Hammar).

Theora mesopotamica (ANNANDALE) is a tellinimorph bivalve species typifying the Hammar Fm. This banal name unfortunately must replace the amusing *Abra cadabra* of EAMES & WILKINS (1957) as ANNANDALE (1918) described and figured it under the name *Corbula (Erodona) mesopotamica*, from "subfossil sandy beds at Nasarieh". It was subsequently moved from the genus *Abra* to the Semelidae genus *Theora* by P.G. OLIVER (*in* BOSCH *et alii*, 1995, p. 263) although retaining the erroneous species name, *T. cadabra*. This material is undoubtedly from the Hammar Formation where we too collected it and where it is associated with a typical brackish oligospecific assemblage. It exists now in the north and northwest portions of the Gulf (BOSCH *et alii*, 1995).

A small oyster, *Saccostrea cucullata* BORN, is also locally abundant in the littoral Hammar Formation deposits. South of Lake Logait it has been dated 4310 γ BP \pm 160 (PURSER *et alii*, 1982). MITCHELL (1958) recorded it near Najaf and MACFADYEN & VITA-FINZI (1978) at Amarah.

Discussion

The freshwater malacofauna of this extensive swamp and lake area is a significant reference for paleoenvironmental reconstructions of Cenozoic

successions. It may be directly compared with that of the contemporaneous tropical Lake Chad (LÉVÊQUE, 1972; BROWN, 1980) where marshes with salinities of less than 1‰ have a comparable area.

Molluscs in Lake Chad do not live in salinities of more than 0.9‰ whereas the Mesopotamian freshwater malacofauna tolerates at least 3‰ (Hammar lake and marsh complex). The benthic African malacofauna too is dominated by Prosobranch gastropods: 83% of the molluscan biomass consists of *Bellamyia unicolor* (45% of all molluscan specimens), the mud dweller *Melanoides tuberculata*, and *Cleopatra bulimoides* that replaces another Thiaridae, our *Melanopsis*. The occurrence of *Bellamyia* piled high on the paleodune shores is, as in Iraq, explained by the buoyancy of the empty Viviparid shells. *Corbicula africana* prefers sandy bottoms, but does not appear to require a specific environment, unlike the unionids *Caelatura* (current) and *Byssanodonta* (hard substrate for attachment). The African *Pisidium* (< 1%) has no equivalent in the Mesopotamian fauna. Pulmonates living on subaquatic plants are mainly large Planorbids and *Bulinus* spp. Thus, despite these minor differences, there is no real inconsistency between the faunas of the Sahelian tropical shallow lakes with aquatic vegetation and the extensive subtropical Mesopotamian marshes and associated lakes.

Study of the dried bottom of a recent polder of Lake Hammar (Fig. C; Pl. 1, fig. 2-3 & 6) enclosed by causeways a few years before (Fig. A.3) showed that, like that of *Typha* and *Phragmites* swamps, the most diverse malacofauna exists where the lacustrine bottom has some rooted vegetation. As we pointed out above, molluscan shells are more abundant on the floor of the marsh channels cleared for boat traffic than they are anywhere else (Pl. 1, fig. 4), due essentially to winnowing and low rates of sedimentation, good oxygenation and nutrient input, and a moderate importation of light shells from adjacent environments (depending on wind-induced currents), but the

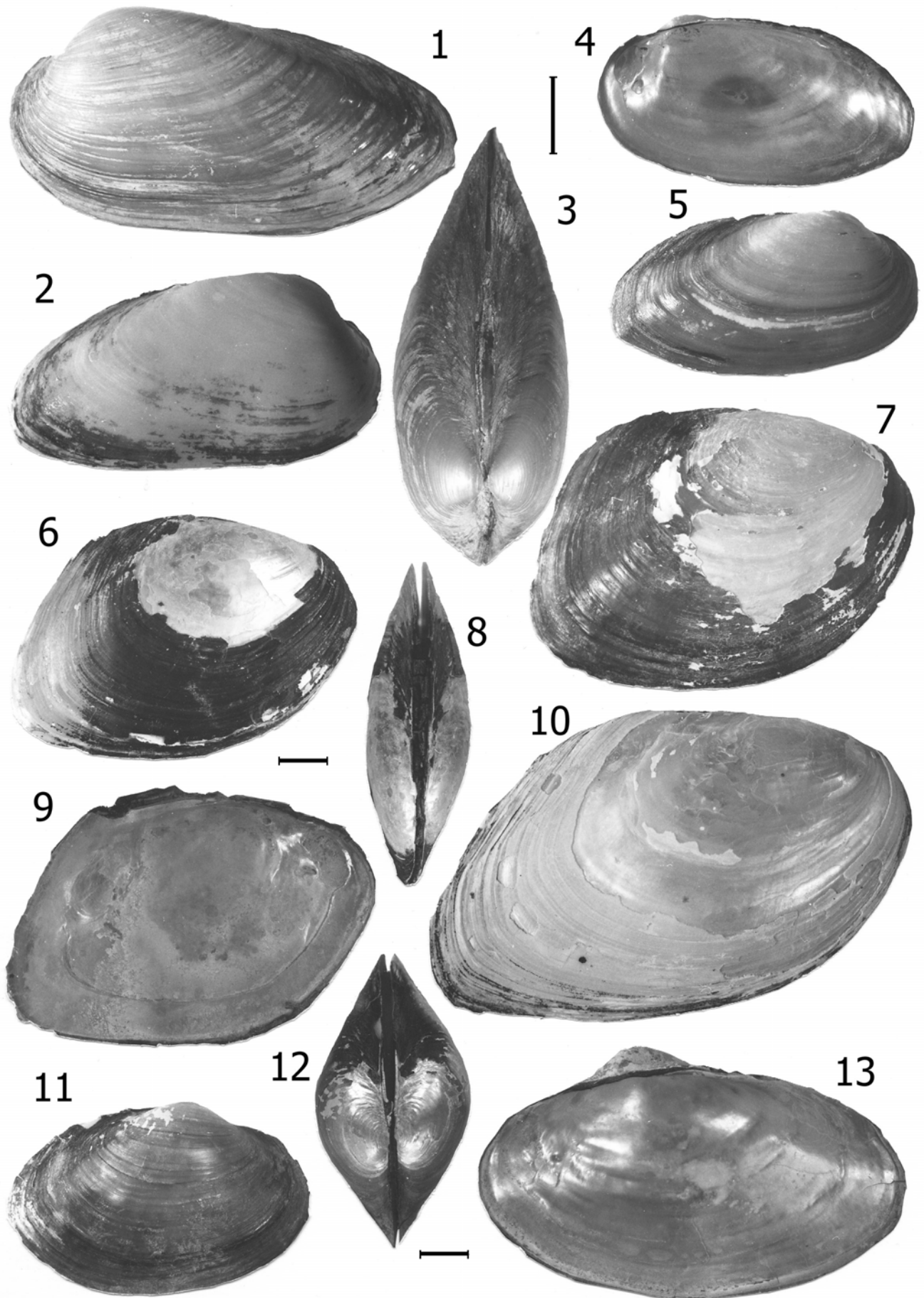
► Plate 2:

Figures 1-5. *Unio tigridis* BOURGUIGNAT. 1 & 3: left valve and umbonal view of a large specimen. 1-2 & 5: marked polymorphism of the shell outline. 4-5: internal and external view of the two valves of a small specimen. Marsh N of the Euphrates river, N of Lake Hammar.

Figures 6-10. *Pseudodontopsis euphraticus* (BOURGUIGNAT). Polymorphism and progressive proportional changes during growth of the shell. 8: umbonal view of the flat bivalve. Lake Hammar.

Figures 11-13. *Anodonta (Anodonta) vescoiana* BOURGUIGNAT. 11-12: Slightly elongated and inflated specimen. 13: internal view of an elongated shell. Lake Hammar.

Scale bars: 1 cm.



biodiversity of the living population in these channels does not differ from that of the other marsh and lake subenvironments.

From a methodological point of view, the local mixture of fossils from a brackish-marine environment (restricted, lagoon-like shallow waters), a few thousand years older than the existing modern freshwater assemblages, is a good example of the errors in interpretation that may be caused by reworking. The resulting symmigiies include discrete fragments of *Balanus* in marsh deposits (North of Lake Hammar), *Balanus*, *Cerithidea cingulata* and *Theora mesopotamica* shells near "Nasariyeh" (ANNANDALE, 1918) and specimens of *Cerithidea cingulata* in the vicinity of Ur and at Basrah (SOYER, 1961). Some small Foraminifera, especially Miliolids, are reworked too, as we found a few specimens in all freshwater deposits where terrigenous sedimentation has been active: in fluvial channels (Tigris, as far upstream as Amarah; Euphrates up to Nassiriyah), and in marshes and channeled lakes, but not in the isolated lakes surrounded by marsh, where bottom sedimentation was unmixed, autochthonous carbonate.

On the other hand, the interpretation of lacustrine foraminifera living occasionally in the salt lakes (e.g. Lake Logait, 2-8‰ after winter rains) immediately south of the old deltaic complex, cannot be ignored but remains doubtful. Indeed, we consider that abundant microfaunas, like that of the lake at Abu Dibbis (80 km NW of Najaf) recorded by MACFADYEN & VITA-FINZI (1978), should not be interpreted as "residual" but rather as the natural population of an intracontinental salt lake. Microfaunas of this type are similar to those of the African Holocene paleolakes (Great Western Erg, Algeria, cf. FONTES *et alii*, 1985; GASSE *et alii*, 1987) where a marine-like fauna (*Potamides*, *Cerastoderma*, Foraminifera, Ostracods) and microflora (Diatoms) must have been introduced by air (probably by water fowl or pelicans, as a human intervention is unlikely). Birket Karun (Fayum, Egypt) also possesses many living *Potamides*, *Cerastoderma*, *Balanus* and divers foraminifera and ostracods but, here, human intervention may be suspected as their introduction can be dated, for it occurred during the XXth century (PLAZIAT, 1991). One is therefore tempted to interpret the marine fauna of the Mesopotamian plain system as a result of aerial seeding, but there is a fundamental difference: in intracontinental salt lakes the marine-like fauna constitutes the whole or the dominant part of the population and it is especially abundant. In Mesopotamia, on the contrary, the marine fossils are sparsely scattered among the unaltered remains of freshwater organisms and are commonly worn and broken.

Accordingly, in the study of the Mesopo-

tamian deposits (surface and cores) the distribution of reworked marine fossils will help to delimit the extent of the Hammar Formation. Its shoreline deposits on the Arabian side of Mesopotamia suggests that the existing, relatively deep marine channel of the western Khor Zubair, located near the front of the Dibdibba Formation (Wadi al Batin fan) is a residual expression of Holocene morphology. To the North, the extensive Quaternary gulf (Holocene Optimum transgression) documented by the most inland (Najaf and Amarah) marine deposits, must necessarily have been filled progressively over time, for the last marine deposits in the vicinity of Ur-Nassiriyah are contemporaneous with cultivation of the Garraf delta by Sumerians (Lagash, around 4500 y BP) (Fig. 2) while the more than meter-thick surficial deposits near the Sumerian cities of Uruk, Larsa and 'Oueili contain freshwater molluscs dated 1190 y BP (± 100) or less (PLAZIAT & SANLAVILLE, 1991). Four of the six ¹⁴C dates at our disposal for the Hammar Formation serve only to confirm the mid-Holocene Optimum age of the transgression (Fig. 1). Dating of samples spaced laterally in succession from the farthest inland trace of the incursion to the existing shore will be required to determine the precise timing of the presumed stages of the regression.

Taking into account the tectonic deformation of the lower Mesopotamian basin in Quaternary times, a scenario involving a single regression is not the only hypothesis possible. The elevations of the youngest marine deposits recorded by MACFADYEN & VITA-FINZI (1978) and PURSER *et alii* (1982) demonstrate a major deformation : +40 m at Najaf, +2 m at Amarah, +1 m S of Lake Logait, -1 m S of Lake Hammar, -4 to -13 m N of Zubair. As the geomorphological analysis of the marsh domain suggests a modern subsident axis from Nassiriyah to Qurna we cannot exclude the possibility that the undated marine deposits around Najaf may be of late Pleistocene age (pre-Hammar Fm: *i.e.* coincident with the Last Interglacial transgression, MIS 5.5).

► Plate 3:

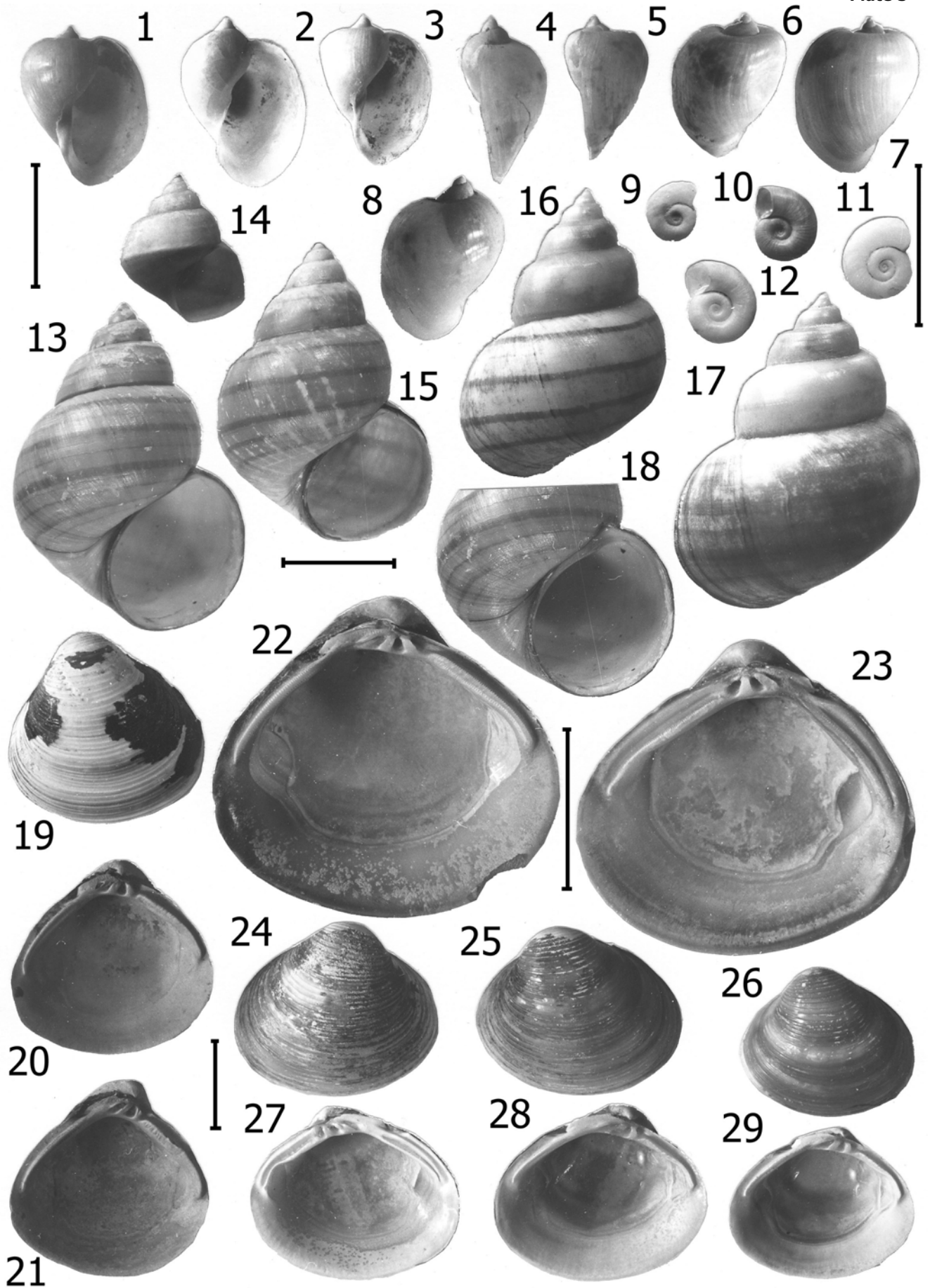
Figures 1-8. *Lymnaea (Radix) gr. auricularia* LINNAEUS. Highly polymorphic shells from one locality: marsh SW of Qurna.

Figures 9-12. *Gyraulus intermixtus* (MOUSSON). Marsh SW of Qurna.

Figures 13-18. *Bellamyia bengalensis* (LAMARCK). 14: a young shell with its carinate whorl. 13-17: more or less elongate specimens. 18: aperture of fig. 13, aperture plane placed in the same plane as the photo. Marsh N of Lake Hammar.

Figures 19-29. *Corbicula fluminalis* (MÜLLER). 19-21: high morphs. 24-29: wide morphs. 22-23: intermediate. See the characteristic striae on lateral teeth of both right and left shells of the same specimen.

Scale bars: 1 cm.



As regards the timing of the termination of marine communication between the Mesopotamian depression and the Gulf, we must consider the possibility of a sudden ending to the strait between the Karun delta and the Wadi al Batin fan, caused by the eustatic (around one meter) drop in sea-level at the end of the Holocene Optimum. This threshold (?) emersion left a continental depression several meters deep to be filled by alluvium from the two Mesopotamian rivers and by lake deposits. The preceding regression at the end of the Last Interglacial high sea-level episode (MIS 5.5) could not have followed the same scenario because the Karun river and Wadi al Batin fans were not as extensive then as they became later.

Conclusion

The original, undisturbed environments of Lower Mesopotamia were destroyed twenty years ago but we suggest that the old files of field observations supplemented by new subsurface data would provide the foundation for a reliable reconstruction of the evolution of this fascinating region. A correct interpretation of the evolution of the deltaic complex of Lower Mesopotamia, with its important geodynamic and archeological implications, requires more precise dating and improved mapping (both in depth and areally) of the limits between marine and freshwater deposits of Holocene (and possibly Pleistocene) age. Provided that paleoecological interpretations are made carefully, the malacofauna is the best tool for this purpose, because reworking of shells appears to be limited.

The respective assemblages of marshes and associated lakes are difficult to differentiate. This justifies the notion of grouping under the name "palustrine" the several environments of the fresh-water areas characterized by a fluctuating water level (seasonally and interannually). These oscillations cause an intimate association in one sedimentary unit of subaquatic and emergent conditions, each marked by a discrete molluscan association and characteristic diagenetic features.

Similarly, the malacofaunas of the major rivers and their common estuarine channel show very limited differences, except at the mouth of the sea. Therefore we assume that the presence of scarce marine species in a fresh-water assemblage is indicative of the existence of a reworked marine unit rather than their association in life in a lagoonal or estuarine environment.

This brief review of the main subaquatic molluscs of Mesopotamia, compared with those of the Lake Chad malacofauna, also suggests

that the provincial effect does not preclude some useful generalizations regarding current interpretations of the Cenozoic paleoenvironments of the western Old World.

From a biogeographic point of view it is clear that the Mesopotamian freshwater malacofauna belongs to the Mediterranean palearctic domain. It is accordingly interesting to note some eastern tropical influences in the brackish-water gastropods (the modern Indo-West Pacific *Cerithideopsisilla*, *Tricula* and *Stenothyra*). Such a biogeographic distribution is not the first record of an eastern link, the Stenothyridae family being present in European Paleogene to Middle Miocene deposits (LOZOUET, 1984, 2005). The Quaternary intruders from the Indo Pacific realm benefited from the warmer transgressive episode of the Holocene Optimum, in the same way as the reef and mangrove malacofaunas did when they invaded the northern Red Sea during the Last Interglacial optimum (MIS 5.5) (PLAZIAT, 1995; PLAZIAT *et alii*, 1998).

Acknowledgements

This report presents the results of field and laboratory studies (1980-1981) carried out by a team coordinated by B.H. PURSER that included M. AL AZZAWI, N.H. AL HASSANI, F. BALTZER, K.M. HASSAN, F. ORSZAG-SPERBER, S.Y. YACCOUB, and the authors. This fruitful cooperation left a feeling of nostalgia for the scientific collaboration that was possible in times of peace. Both the elaboration of and improvements in this contribution benefited from the help of F. BALTZER, B. GRANIER, N. SANDER, P. LOZOUET and an anonymous reviewer. Their aid is gratefully acknowledged.

► Plate 4:

Figures 1-6. *Cerithidea (Cerithideopsisilla) cingulata* (GMELIN). 1-4 & 6: living snails, (1) with an Ostreid shell on its back; (6) axial view of the last whorl. The dorsal half of specimens (3-4 & 6) is eroded by microboring algae; their attack on the lower half is prevented by the ploughing behavior of the snail. Shatt al Arab estuarine mouth, Fao. 5: fossil specimen from the Holocene Hammar Formation. S of Lake Logait.

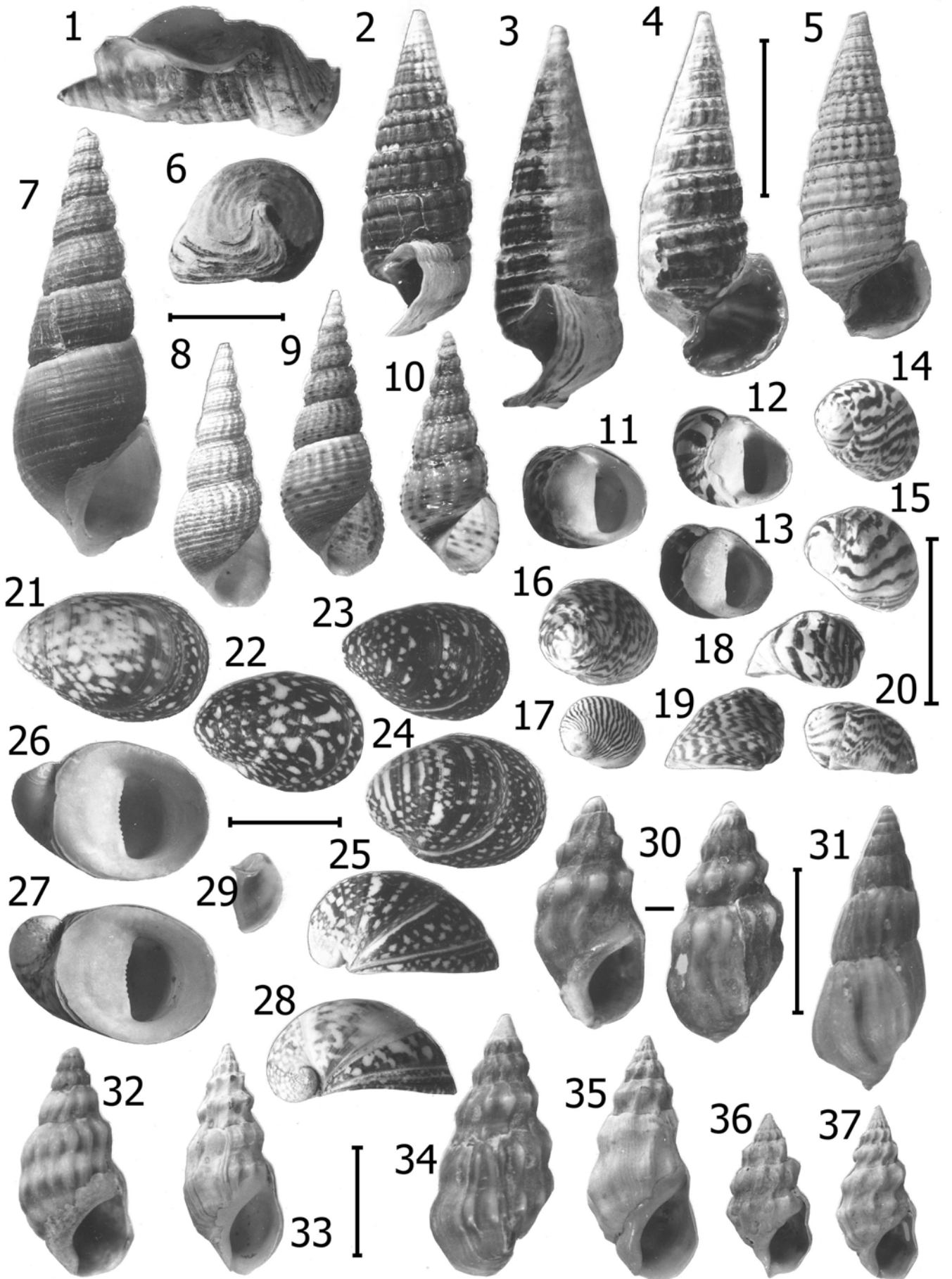
Figures 7-10. *Melanoides tuberculata* (MÜLLER). Diverse ornamentations and patterns of whorl development during growth. Lake Hammar.

Figures 11-20. *Theodoxus (Neritaea) jordani* (SOWERBY). Polymorphism in one locality. Marsh N of Lake Hammar.

Figures 21-29. *Neritina (Dostia) schlaeflii* MOUSSON. 21-26: polymorphism and diverse color ornamentation. 29: internal view of the operculum. Mouth of the Shatt al Arab estuary, Fao. 27: Holocene fossil, NE of Basrah.

Figures 30-37. *Melanopsis (Melanopsis) praemorsum* (LINNAEUS). 30-33: high degree of polymorphism of an estuarine upper reach population, NE of Basrah. 34-37: lacustrine population of Lake Hammar.

Scale bars: 1 cm.



List of the cited taxa.**Gastropoda, Prosobranchia**

- Neritina (Dostia) violacea* GMELIN, 1790
Neritina (D.) schlaeflii MOUSSON, 1874
Theodoxus (Neritaea) jordani (SOWERBY, 1836)
Theodoxus (N.) mesopotamicus (MOUSSON, 1874)
Theodoxus (N.) euphraticus (MOUSSON, 1874)
Theodoxus (N.) macrii (RECLUZ, 1841)
Bellamya bengalensis (LAMARCK, 1822)
Bellamya unicolor (OLIVIER, 1804)
Valvata sp.
Amnicola (Alocinna) ejecta (MOUSSON, 1874)
Tricula palmyrae (DAUTZENBERG, 1894)
Stenothyra iraqensis DANCE et EAMES, 1966
Bithynia badiella PARREYSS, 1849
Melanoides tuberculata (MÜLLER, 1774)
Cleopatra bulimoides (OLIVIER, 1804)
Melanopsis (Melanopsis) praemorsum (LINNAEUS, 1758)
Cerithidea (Cerithideopsis) cingulata (GMELIN, 1790)
Potamides conicus (BLAINVILLE, 1826)

Gastropoda, Basommatophora

- Lymnaea (Radix) auricularia* LINNAEUS, 1758
Lymnaea (R.) tenera PARREYSS, 1849
Lymnaea (R.) canalifera MOUSSON, 1874
Lymnaea (R.) lagotis SCHRANK, 1803
Gyraulus albus (MÜLLER, 1774)
Gyraulus convexiusculus (HUTTON, 1850)
Gyraulus intermixtus (MOUSSON, 1874)
Bulinus contortus (MICHAUD, 1829)

Bivalvia

- Saccostrea cucullata* (BORN, 1765)
Unio tigridis BOURGUIGNAT, 1853
Pseudodontopsis euphraticus (BOURGUIGNAT, 1853)
Anodonta (Anodonta) vescoiana BOURGUIGNAT, 1857
 (*Abra cadabra* EAMES et WILKINS 1957 = *Theora cadabra* EAMES et WILKINS 1957 in BOSCH et alii, 1995 = in reality *Theora mesopotamica*)
Corbicula cor (LAMARCK, 1818)
Corbicula fluminalis (MÜLLER, 1774)
Corbicula tigridis MOUSSON, 1874
Theora mesopotamica (ANNANDALE, 1918)

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