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Mollusks of the Pleistocene Al-Qarn Formation of the Jordan Rift-Valley in Jordan

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with 5 plates

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Abstract

The Jordan Valley south of Lake Tiberias has post Messinian deposits with saline character succeeded by fresh water deposits. These were deformed by further vertical and horizontal movements in the Jordan Valley Rift. Those encompassing the Al Qarn Formation after deformation came to lie next to sands and gravels of an ancient Jordan River and were inundated by Lake Lisan and covered by the bottom deposits of its salty waters. They have a structural contact to deposits of the Tayba Formation that formed in a sea at late Oligocene to early Miocene times. Exposure of Al Qarn Formation was created when the King Abdulla Canal was constructed. Since about twelve thousand years and after Lisan lake had dried up and shrank to become the Dead Sea, the Al Qarn Formation had been present as it is now. Of the fauna which at Al Qarn times lived in a lake and in creeks issuing into it, the shells of the mollusks have been preserved, especially well in one layer that is of a fine sandy and marly composition.

Dominant and well visible shells belong to *Melanopsis*, of which 5 species are recognized, and one of these is described as new, *Melanopsis salamei*. Very common is *Valvata saucyi* that is much smaller and found in the screened washings. They are evidence for shallow beach environment in case of *Melanopsis*, and vegetated pond environment in case of *Valvata*. Also present is a *Theodoxus* that closely resembles the species still living in Jordan also next to the outcrop in King Abdulla Canal. Common is *Bithynia syriaca* that connects to Erq el Ahmar Formation and no longer lives in Jordan. Juvenile shells of a *Hydrobia* could belong to the same species that is still present in the region. The tiny *Islamia* is new to the region, here described as *Islamia jordanica*, but also no longer living here. *Melanoides* from Al Qarn Formation has a different early ornament of the shell which distinguishes from the species of that genus that lives in Jordan now and is named *Melanoides abuhabili*. A small planispiral *Valvata* closely resembles *Valvata piscinalis* that occurs in the region but not in Jordan and juvenile shells of *Galba* are close to *Galba truncatula* that lives in creeks in Jordan. Very common is *Gyraulus* with quite variable shell, and a small limpet that according to the shape of its embryonic shell is a *Ferrissia* of which the species is here newly described as *Ferrissia urdunica*. A tiny bivalve is placed with *Pisidium* and the large shells of *Unio* were recognized only in the field, but shells were too brittle to be collected.

The fauna of mollusks of Al Qarn Formation connects to the gastropods of fresh water which live in Jordan today, but also differs for example in regard to *Physa* which was not present and by a few species which are no longer found. Differences are minute in regard to the fossils of Erq el Ahmar and Ubeidiya Formations which are exposed near Lake Tiberias. Their age is closer to that of Al Qarn Formation and all three had been deposited well before the existence of ancient River Jordan that ended in Lake Samra and flowed just to the west of the outcrop before it and the inclined beds of Al Qarn Formation became inundated by salty Lake Lisan.

Zusammenfassung

Im Jordantal südlich vom See Genezareth befinden sich lokal Aufschlüsse in denen im Süßwasser abgelagerte Sedimente anstehen. Sie wurden entlang von Störungen am Rande des Rift-Tales verformt, an denen auch weiterhin Bewegungen stattfinden, und dabei zum Jordantal hin gekippt. Vor der Ablagerung der von Flussablagerungen beeinflussten Sedimente herrschten im Jordangraben vom Mittelmeer her kommende salzige Gewässer vor, die noch im Anschluss an die Messinische Phase entstanden waren. Ein Kontakt zum Mittelmeer war aber vor der Ablagerung der Al Qarn Formation beendet. Diese Formation steht westlich der Ortschaft Abu Habil am Anschnitt des König Abdulla Kanals, etwas südlich der Hügelkette Al Qarn an. Den nach Westen verkippten Flusskiesen sind mergelige Seeablagerungen eingeschaltet, die eine reiche Molluskenfauna enthalten. Eine Störung, etwa entlang des Verlaufes des Kanals, trennt die Al Qarn Formation von der noch stärker tektonisch beeinflussten Sedimentabfolge der Tayba Formation aus oligozän-miozänen Meeressablagerungen. In diese eingetieft wurden die noch unverformten Sande und Gerölle eines Jordanflusses abgelagert, der zur Zeit des Eem-Interglaziales in ein damaliges Totes Meer, den Samra-See, mündete.

Tertiäre Meeresssedimente der Tayba Formation, pleistozäne Al Qarn Ablagerungen, wie auch die Sande und Kiese aus den Zeiten des Samra Sees bildeten anschließend – eng beieinander liegend – den Grund des salzigen Lisan-Sees, der bis vor etwa 15000 Jahren das Jordantal bis zum See Genezareth bis zu einer Höhe von etwa -170 m ausfüllte.

Von der Fauna, die im Süßwasser zur Zeit der Ablagerung der Al Qarn Formation lebte, liefert eine mergelig-feinsandige Schicht Molluskenschalen, von denen besonders jene von *Melanopsis* schon im Gelände auffallen. *Melanopsis* stellt eine Gruppe von 5 Arten, von denen *Melanopsis salamei* hier neu beschrieben wird. Sehr häufig kommt auch *Valvata saulcyi* vor. Eine kleine, plan aufgerollte *Valvata* ist der *Valvata piscinales* sehr ähnlich und leicht mit *Gyraulus* zu verwechseln. Zudem ist *Theodoxus* anzutreffen, die – mit ganz ähnlicher Gestalt – heute im Kanal neben dem Aufschluss lebt. Häufig ist auch *Bithynia syriaca*, die jener aus dem Aufschluss der Erq el Ahmar Formation auf der westlichen Seite des Jordan, nahe der Mündung des Yarmouk-Flusses gleicht. Daneben ist selten eine *Hydrobia* anzutreffen, häufiger die ebenfalls kleine *Islamia*, die heute nicht mehr in Jordanien auftritt und hier als neue Art *Islamia jordanica* beschrieben wird. *Melanoides* ist heute in Jordanien häufig, doch handelt es sich aufgrund des Ornaments der frühen Windungen der Schale um eine von der heutigen unterschiedene Art, hier als *Melanoides abuhabili* beschrieben. Die Jugendschalen von *Galba* ähneln jenen, der heute in Jordanien lebenden *Galba truncata. Gyraulus* mit sehr variabler Schale lebte in Tümpeln der Al Qarn Zeit häufig und fehlt heute zumeist in jordanischen Gewässern. Die winzige Napfschnecke *Ferrissia* ist für Jordanien neu und wird als *Ferrissia urdunica* neu benannt. Daneben wurden Muschelschalen einer schlecht erhaltenen, großen *Unio* angetroffen und häufiger treten die sehr kleinen Klappen von *Pisidium* auf.

Die Arten der Al Qarn Fauna ähneln den heute im Süßwasser Jordaniens lebenden Schnecken und Muscheln, weisen aber auch deutliche Unterschiede auf. Ähnlich steht es mit den Faunen der lithologisch und strukturell ähnlichen Vorkommen von Erq el Ahmar und Ubeidiya, die weiter nördlich, in der Nähe des Sees Genezareth anstehen. Das Alter dieser Faunen kann dem der Al Qarn Formation nahe liegen, und alle drei Formationen entstanden deutlich früher als die Ablagerungen des in den Samra See mündenden Jordan vor Bildung des salzigen Lisan-Sees.

1 Introduction

The Jordan Valley in northern Jordan represents a predominantly flat area between the steep slopes to the eastern side and the less steep slopes on the western side. Into that plane the modern Jordan River has since more than 15.000 years ago – and with the shrinking of the Lake Lisan to form the Dead Sea cut its bed. It is bordered by steep sides and connected to many relatively newly eroded side valleys. Here Jordan river meanders in a narrow flood plane (Zor). Most of the side valleys extending from the Zor are narrow and have a creek that in most cases has its origin in a spring, or is derived from irrigation water. Only a few creeks and their connected small canyons continue into the steep side valleys coming from the eastern highlands. Only two rivers merge with this

northern Jordan Valley, one in the north is occupied by the Yarmouk River and one further south is occupied by the Zerqa River, but there are also several smaller creeks which are connected to deeply incised valleys.
Most of the Jordan Valley plane represents the former lake bottom of Lake Lisan which covered the area for several ten-thousand years from around 80.000-70.000 to around 14.000-12.000 years ago (HAZAN et al., 2005 and GHAZLEH & KEMPE, 2009). The former beach of that lake can still be recognized at the base of the eastern slope of the Jordanian highlands at a level of around 170 m below sea level. Into this former lake floor and after the lake has become dry, the Jordan River has excavated its course, now forming the flat Zor in which the river meanders and that is bordered by steep sides.
Along the margin of the Jordan Valley plane to the modern Jordan Valley King Abdulla Canal has been constructed in which water derived predominantly from Yarmouk River flows. It is used for irrigation and also for fresh water supply of Amman, being partly pumped up to the city of Amman before reaching the town of Deir Alla.
At the eastern slope excavated during the construction of the canal, to the SW of Al-Qarn military station and near and just SW of the town of Abu Habil, a sequence of sediments is exposed that has a strong dip towards the Jordan River. Its exposure lies at about the level of the former bottom of Lake Lisan and has only been opened to the surface in the cut made by the construction of the canal. Thus the section is found when one follows the margin of the canal going north from the bridge of this canal across a small road. When following the concrete margin of the canal toward the North for about 50 m the exposure with well preserves fossils in it is reached, and its exact location is found where the large white shells of *Melanopsis* are be recognized on the grey marly sands.

2 History of related strata

When, after the Messinian Salinity Crisis the basin of the Mediterranean Sea filled again with sea water up to the Ocean sea-level line, sea water flowed into the Jordan Rift-depression (GARFUNKEL, 1988). At the very beginning of the Pliocene a narrow bay formed that extended through the Bisan (Yizreel) Valley from the Mediterranean Sea into the Jordan-Dead Sea-Wadi Araba (Arava). Here, water evaporated and an evaporite-rich series, consisting mainly of halite, reached a thickness of a few kilometers in the Dead Sea basin. It was also of considerable thickness in the Jordan Rift Valley from the area of the Dead Sea to the area of Lake Tiberias (BLANCKENHORN, 1896; NEEV & EMERY, 1967; MARKUS & SLAGER, 1985). This “Dead Sea Group” of ZAK (1967) encompasses the entire sequence deposited in the Dead Sea Basin since it was first created topographically.
The structural history of that Rift Valley and connected to it the movement of the Levant relative to that of Arabia is a controversial matter which has found quite different interpretations suggested by different of authors in regard to the time in which movements occurred and what were their results. The base of the rift valley, that is formed by rocks of Late Cretaceous and Early Tertiary age resembling those exposed on the Eastern rift margin and the highlands above it, is interpreted to lie more than 7 km below modern surface of the Jordan Valley and the Dead Sea surface (NIMROD, 2012). FLEXER et al. (2005) summarized that the Mid-Oligocene emersion and regional uplift resulted in erosion, and since earliest Late Oligocene a sinistral strike slip along the Jordan-Gulf of Aqaba line opened a chain of grabens. The detailed history of these structures is not described and the morphology of the Rift Valley is quite problematic until about the formation of Lake Lisan at about 80.000 years ago. Rift Valley formation is still unresolved in detail, as can also be assumed from the stratigraphic compilation illustrated by HIRSCH (2005a: fig. 18H.9).
During the Pliocene a sequence with much deposition in saline environment called Sedom Formation and Amora Formation were proposed by ZAK (1967). An additional unit “Upper Dead Sea Group” was suggested by NEEV & EMERY (1967) to hold the Pleistocene sequence of the deposits here. Sediments of the Dead Sea Group consist predominantly of salt and other chemical deposits and of gravel and sand that has been dumped into the saline deposits from the sides, predominantly the eastern side of the Dead Sea Basin.
Near Lake Tiberias almost 1.000 m of saline deposits were drilled in a well described by MARCUS & SLAGER (1985). From seismic profiles it has been reconstructed that the sediment fill of the basin amounts to a column of 7 km and of these 3 km have been suggested to belong to sediments of stratigraphical position between Miocene and base of the Pleistocene. The drilled section going for 4.25 km into the ground discovered sediment consisting predominantly of saline deposits and basalt dikes. The pre-rift ground was not encountered (SLAGER et al., 1983). It ended in a conglomerate of unknown age that was interpreted as of supposedly Miocene age. This hole was drilled half way from the southern shore of Lake Tiberias to Yarmouk River. Only the upper few hundred meters of sediment were composed of clastic rocks.
Below the Lake Tiberias area the presence of salt diapirs is reconstructed (NIMROD, 2012). The inner structure of the salt and basalt beds in the Northern Jordan Valley near the mouth of the Yarmouk according to the interpretation of NIMROD (2012) evolved through processes of endemic tectonics, sedimentation, evaporation and magmatic activity, all occurring in a subsiding basin along a continental transform. The actual course of

these rock forming processes is quite disputed among scientists working in the region and is actually quite unresolved, including the processes of sedimentation between post-Messinian deposition in saline environment and Pleistocene deposition by fresh water in streams and lakes covering the time of several Million years when probably very active rifting occurred alongside.

BANDEL & SALAMEH (2013) ventilated the idea that during the Messinian Salitity Crisis, and due to it the massive lowering of the level of the Mediterranean Sea not only the Nile formed a deep canyon but there was also a canyon eroded from the shelf edge near Haifa to connect with the Jordan Rift Valley. When the Mediterranean Sea filled again up to the level of the Atlantic Ocean this former canyon can have served as strait by which sea water entered the Rift and here evaporated forming the thick salty units which now pressed out as structures forming salt domes (diapirs), for example, the famous mount Sedom on the western side of the Dead Sea.

Sediments of a lagoon of Pliocene age from the Yizreel Valley, the "Bira Formation" of SCHULMAN (1959), were also recognized in the samples from the well at the south end of Lake Kinneret (Lake Tiberias) interpreted to represent 160 m of marls, clays and sands (MARCUS & SLAGER, 1985). Ostracods found here were interpreted to indicate brackish to salty conditions during deposition of the sediments suggested to be equivalent to Bira Formation.

After a hiatus, it is interpreted, that the fresh water deposits of Gesher Formation follow, consisting in the outcrop north of Lake Tiberias of 20–50 m of limestone, clays, and marls. Gesher Formation is exposed about 100 km further north of the outcrop of Al Qarn Formation. It has been reconstructed to be covered by the "Cover Basalt" that is determined as basal Pleistocene in age. Gesher Formation contains freshwater mollusks according to HOROWITZ (1979, 2001), including *Melanopsis*, *Melanoides*, *Viviparus*, *Dreissena* and a species of *Hydrobia.* Gesher Formation is interpreted to overlie sediments which were predominantly deposited under saline conditions and have formed in fresh water environment that is interpreted to predate the Cover Basalt with latest Pliocene age (NIMROD, 2012). But, the fauna of Gesher Formation has also been determined to be of an age of about 780.000 years by HELLER & SIVAN (2001) while HOROWITZ considered it to be more than 1 Million years old. Interesting is the presence of the gastropod *Viviparus* and the clam *Dreissena* in Gesher Formation, both of which can have arrived here by migration from the Paratethys on a route that in general follows the modern Orontes.

Erq el Ahmar Formation as described in detail by TCHERNOV (1975a) is exposed on the western side of the Jordan just south of its confluence with Yarmouk River. It consists of a sequence of beds which are inclined with a dip of 25° towards the Jordan River and are capped by horizontal beds of Lisan Lake deposits. Between both formations lies a distinct unconformity. The Erq el Ahmar Formation includes limnic deposits consisting of clay and marl intercalated with sand and silt containing several layers which are rich in mollusk shells. TCHERNOV (1975a) suggested an age of early Pleistocene and older than Ubeidiya Formation. *Theodoxus* is here present with the same species as is in Al Qarn, as is *Valvata* with *Valvata saulcyi*.

A *Hydrobia acuta* was determined (TCHERNOV. 1975a: pl. 1, fig. 5) that resembles what can still be found living in Jordan and was also noted in Al Qarn Formation, while *Falsipyrgula barroisi* (DAUTZENBERG, 1894) that lives in the canal near the Al Qarn Formation outcrop but is not found as a fossil in the deposits of that formation. *Bithynia syriaca* BLANCKENHORN, 1897, is the same as the newly discovered *Bithynia* in Jordan from Al Qarn Formation. Both species recognized in the genus *Melanopsis* of the Erq el Ahmar Formation by TCHERNOV (1975a) and described again by HELLER & SIVAN (2002a) also occur in the Al Qarn Formation. The three species of *Melanoides* which have been recognized by TCHERNOV (1975a) may actually belong to one variable species due to the high variability that can be observed regarding fully grown *Melanoides tuberculatus.* This genus of a thiarid snail is found also in Al Qarn Formation and as living species in various localities in Jordan, but as described below with differences in regard to the ornament of its early teleoconch. But that part of the shell, in case of Erq el Ahmar specimens remains unknown since it was not described, thus comparison with the fossil species from Al Qarn Formation as well as with *Melanopsis tuberculatus* living in the area nowadays is not possible. *Lymnaea lagotis* described by TCHERNOV (1975a) also occurs in Al Qarn Formation (*Galba*). Also the presence of *Gyraulus* was noted from Erq el Ahmar Formation, and obviously this genus is more variable in the Al Qarn Formation. *Unio* and *Pisidium* were found at both localities and only the absence of *Dreissena* from Al Qarn Formation is a real difference.

Thus the composition of the fauna from Erq el Ahmar is quite similar to that of Al Qarn, with the exception of *Viviparus* and *Dreissena,* both of which are not found in the latter. *Viviparus* and *Dreissena* feed by filtering phytoplankton from the water, and this special mode of life may not have been possible in the Al Qarn environment, which could explain their absence just as well as differences in the time of deposition of these formations. The assemblage of species of *Melanopsis* is similar but two different forms have been recognized from Al Qarn Formation. To suggest a difference in age of both localities based on the occurrence of mollusk shells would thus be difficult, since the presence of *Falsipyrgula* in Erq el Ahmar Formation, but not in Al Qarn Formation, but its presence as species living in the King Abdulla Canal next to the latter, could with the same reasoning be interpreted to consider Al Qarn Formation to be the older of the two deposits.

The sediments of both formation had been deformed and their strata strongly inclined, and truncated before the deposits of Lake Lisan were placed on them. When the discussion of Erq el Ahmar Formation as by HIRSCH (2005a) is considered as well, matters become confused even more since he suggested an age of 2 Million years for the formation.
The Ubeidiye Formation has been interpreted to overly Erk el Ahmar and it is overlain und thus older than Naharayim Formation (interglacial Yarmouk and Jordan River deposits), which in turn is considered to represent the base to Lake Lisan deposits of the equivalent to the last glacial period (BENDER & KAUFMANN, 1971; HIRSCH 2005a; NIMROD, 2012). The locality of its exposure lies on the western side of the Jordan 3 km south of Lake Tiberias (= Sea of Galilee, Lake Kinneret) and next to Tell Ubeidiya (TCHERNOV, 1975a: fig. 1).
The Ubeidiya Formation as described by SCHULMAN (1962) and HELLER & SIVAN (2002b) is about 30 m thick and consists of alternating limnic and fluviatile deposits. Bedded clay and silt, oolitic limestone (probably washed and size-sorted terrestrial oncoids as present in the deposits of Al Qarn Formation) and soft chalk contain *Melanopsis* and plant and fish remains. Above are conglomerates holding implements as well as vertebrate bones among other those attributed to *Homo erectus*. Its depositional environment has been interpreted to represent a river discharging into a lake with swamps. Bones of a fossil species of dogs, of hippopotamus, gazella, deer, fossil horse and also small shrews were found.
The gastropods from Ubeidiya Formation are *Valvata saulcyi, Bulimus hawaderiana (= Bithynia), Lymnaea lagotis, Planorbis planorbis, Gyraulus piscinarum,* and *Ancylus fluviatilis*. Thus, gastropods from this locality may be similar to those of Al Qarn Formation, and neither *Viviparus* nor *Dreissenia* were present.

3 The Al Qarn Formation

3.1 General description

The sediments of Al Qarn Formation consist of a series of fluviatile gravel with an intercalation of fine marly sand deposited in quite water of a lake. In a sequence of fluviatile gravel about 25 m of lacustrine deposits are intercalated, which are again covered by gravel. The whole formation is inclined with a dip of about 50° towards the Jordan Valley (BANDEL & SALAMEH, 2013; ALHEJOJ, 2013).
Much of the carbonate, especially larger particles, represents pisolites which have formed in soil and have become reworked by erosion. Particles may be concentrated in coarse gravel composed of oncolites or fine beds with smaller coated grains concentrated which resemble oolites. The fluviatile gravel is composed predominantly of material that has been eroded on the eastern highland and consists of Paleogene to Late Cretaceous material, consisting predominantly of flint and limestone.
This whole series is exposed on the eastern side of the King Abdulla Canal, while the western side along the small road at the canal margin in part belongs to the Tayba Formation of Oligocene-Miocene age (BANDEL & SHINAQ, 2003). The contact between Tayba and Al Qarn formations is structural and represented by a fault.
Exposed Tayba beds in the Wadi Al Qarn between Canal and the margin of the Zor have a much steeper dip towards the Jordan River than that of the beds of the Al Qarn Formation. In that Wadi al Qarn 150 m to 200 m of conglomeratic to sandy-silty, well bedded sediments are exposed. The exact thickness of the series is difficult to evaluate due to the quite intensive faulting especially near the eastern end of its outcrop in Wadi al Qarn and in the middle portion of the sequence beds may be in vertical position but also folds are present.
Tayba Formation formed about 24 million years ago, when the area – now occupied by the Jordan valley in northern Jordan between the towns of Abu Habil and North Shuna – was inundated by the sea coming from the north, and most probably connected to the Indo-Pacific Ocean via the Damascus Basin. What is now the steep eastern slope of the Jordan rift valley at that time represented the shore, with unknown width of the sea towards its western extend. The Dead Sea transform fault with its branch situated in the eastern side of the Jordan valley did not only displace rocks downwards but also has a strong lateral component.
The Dead Sea transform, which should have its place near the modern incision of the Jordan River has been interpreted by PICARD (1951) and GARFUNKEL (1981) to have formed during the Oligocene and Miocene within a low relief landscape which drained towards the Mediterranean. They suggested that the major change in morphology and the establishment of the Dead Sea transform and the establishment of a narrow rift valley occurred only in the Early Pliocene, and that has been also the interpretation by SEGEV (2005) based on dating basalt flows in the region. But the deposition of thick river-based conglomerates in the area of the Rift Zone during the early Miocene as documented by BANDEL & SHINAQ (2003) rather points into a different direction with a larger morphological difference between Arabia and the Rift collecting the material produced by erosion from the eastern highlands much earlier than Pliocene. The time available amounts to 10 Million years and more, before the Messinian salinity crisis and the drying up of much of the Mediterranean Sea.
Thus it can be concluded that in the area of the exposure of Al Qarn Formation most of the depositional history between Tayba Formation and Al Qarn Formation is still unresolved, but that an unknown rock column

including salts and other sediments formed by evaporated sea water as well as terrestrial deposits coming from especially the eastern highlands are present, overlain by an just as unknown thickness of terrestrial sediments formed after the sea has access to the area during the Pliocene and part of the Pleistocene.
The marly deposits in the sequence of the Al Qarn Formation are partly consolidated by calcareous cement. In the beds with well preserved fauna, the sand is still unconsolidated and no dissolution of shell material took place. Thus, aragonitic shell substance is still preserved and no cement was formed. Original shell structure of gastropod shell, as was checked in case of *Theodoxus*, *Hydrobia* and *Melanopsis* with predominantly aragonitic composition with crossed lamellar structure is preserved basically unchanged with only the primary organic components having disappeared.
The sediments of these beds could simply be washed through a screen to extract the fauna. In the field the presence of the fauna is spotted easily by shells of the common *Melanopsis.* While they are well preserved in one layer, they have been dissolved in others, but only after the sediment had been consolidated by cementation. These sandstones thus have numerous cavities which have the shape of *Melanopsis* and thus document its former presence. Here, the calcareous components including the aragonitic shells became dissolved and partly re-precipitated as cement.
A variety of species of stylommatophoran pulmonates and the caenogastropod *Pomatias* were washed into the lake and had formerly lived near it on land. The land snails have thin shells in which the original organic shell material has been decomposed so that they do not survive the washing of the sediment. But their initial whorls are more solid and are usually well preserved. Shape and size of the embryonic whorls of the land snails would allow a comparison to those species now living in Jordan and probably determination to the species in many instances. Their early life usually begins in relatively large eggs with much yolk available to the embryo and the young hatch with a much larger shell than is found among the species of fresh water gastropods.
Species determination of land snails can be of value in the reconstruction of the climate, since data are well known regarding the living land snails of the Levant (HELLER, 1993), but that was not undertaken in the present study.
Fragments of vertebrate bones are present as well as bones and teeth of fish. A large tooth found could have come from a crocodile. Ostracods and crab claws of *Potamon* represent the crustacean inhabitants of the lake (pl. 1/1–4). The fresh water crab *Potamon* still lives along most creeks and rivers in Jordan. It represents an amphibious animal with rapid movement on land as well as in water. During day times it usually hides in burrows which it excavates at the margin of creeks. The species of ostracodes which could be determined from the Al Qarn Formation are still the same or close to the ones living in Jordanian waters (det by Steffen Mischke, 2013).

3.2 The mollusks of Al Qarn Formation: description and discussion

Subclass Neritimorpha GOLIKOV & STARABOGATOV, 1975
Superfamily Neritioidea RAFINESQUE, 1815

Genus *Theodoxus* MONTFORT, 1810

Theodoxus cf. *jordani* (SOWERBY, 1836)
(Pl. 1/5–8)

Theodoxus has a short shell with few whorls with a thin outer calcitic layer and a thick inner aragonitic layer (pl. 1/8). The color pattern lies within the outer calcitic layer and can be well preserved in fossil shells and also in case of the specimens from Al Qarn Formation (BANDEL, 2001: figs 36–40).
The embryonic shell composes the first whorl and is clearly set off from the teleoconch by its usually uniform, commonly white color. It has rounded shape and measures approximately 0.8 mm across. With begin of the teleoconch the mode of calcification of the shell changes and the following outer layer of the teleoconch is calcitic. This change is also documented on the outside by the presence of long needle-like crystallites visible from the margin of the embryonic shell with the teleoconch (pl. 1/7). The teleoconch consists of about 2.5 whorls with pattern of color by irregular dark zigzag ribbons on light background. About 4 to 7 broad ribbons may be present on the first whorl of the teleoconch. This zigzag pattern is very variable among different individuals within the species.
The shape of a shell with one teleoconch whorl is usually hemispherical with rounded apex and flattened base, and width is larger than height (pl. 1/5). The inner lip of the aperture is smoothly covered by callus and has a straight inner (columellar) edge without teeth. In the second whorl of the teleoconch the relative height of the

whorl increases and whorl sides have become more or less flat. In many individuals a shoulder develops and may form a rounded ridge that may or may not be accompanied by a depression below it.
Fully grown shells are higher than wide, reach 10 mm in height and 9 mm in width. The callus cover of the inner lip can be rounded and the margin of the inner lip (columellar edge) may appear evenly concave. The calcified operculum is provided with a ridge and a peg representing a solid structure on the inner side of the columellar margin (pl. 1/6). With this peg on its inner side the operculum is held in place when the animal is withdrawn into its shell.

Remarks: The color varieties of the now living populations have often been placed in different species according to the type of pattern. Since color patterns are often also found among fossil species a profusion of names has been created among fossil representatives of *Theodoxus* (BANDEL, 2001). The color pattern of axial ribs may continue to the body whorl and ribs can also fuse marginally to form a pattern of white dots or ribs fuse with each other turning the color of the shell into a uniform black. Not only color but also the shape of the shell may vary from simple and rounded and from shells as wide as high to higher than wide. Also the angle at their apical side and the presence or absence of a groove on the side varies among individuals.
A total transition in shapes between forms that have been determined as *Theodoxus orontis* BLANCKENHORN, 1897, to such that are determined as *Theodoxus jordani* by SCHÜTT (1984: pl. 2, figs 1, 2) occurs. Thus *Theodoxus orontis* is interpreted to represent a variety of *Theodoxus jordani*.
The protection of the animal provided by the operculum is quite effective and can prevent the crab *Potamon* to use *Theodoxus* as food, as was observed in Jordanian springs and clean creeks with *Theodoxus* and *Potamon* living side by side. Crabs resembling modern *Potamon* from Jordanian rivers and creeks also lived in Al Qarn Lake as is documented by preserved parts of their claws. Fossil *Theodoxus* thus had to protect itself from attacks of the crab as well.
Theodoxus jordani occurs in almost all clean springs and creeks in Jordan (BANDEL & SALAMEH, 1981). The species of this genus which lived in Al Qarn Lake were very similar in shell shape to those that live in the Yarmouk River, in Lake Tiberias (TCHERNOV, 1975b; DAGAN, 1971), in the northern part of King Abdullah Canal, and in the Orontes (SCHÜTT, 1983).
HOROWITZ (1979) noted that *Theodoxus jordani* was basically unchanged from the base of the Pleistocene to recent times. *Theodoxus jordani* from the Erq el Ahmar Formation according to TCHERNOV (1975a: pl. 1, fig. 1) is a very variable species that also includes such forms that have been described as *Neritina karasuna* BLANCKENHORN, 1897, and *Neritina orontis* BLANCKENHORN, 1897. The shells of the adults of *Neritina* are very similar to those of *Theodoxus*, while their ontogeny as well as their living environment distinguishes both from each other quite clearly (BANDEL, 1982, 2001). *Neritina* has a plankton-feeding larva and thus a larval shell, and it lives in rivers and creeks that can be reached from the sea. The early ontogenetic of *Neritina* as well as that of *Theodoxus* during further growth that is usually in the environment of fresh water is mostly dissolved and thus these differences are no longer detectable and differentiation is even less easy.

Subclass Caenogastropoda COX, 1959
Superfamily Rissooidea GRAY, 1847
Family Bithyniidae GRAY, 1857 (= Bithiniadae GRAY, 1857 = Bulimidae GUILDING, 1828)

The Bithyniidae have a globular shell with raised spire, a thick calcareous, concentric operculum. Their mode of life is filter feeding with modified gill. Members of this family of the Rissooidea have their own evolution within the fresh water environment since a long time and according to PONDER (1988) and HEALY (1988) they have distinct anatomical characters of their soft body. Their history ranges back to at least the late Jurassic (BANDEL, 1991). According to WENZ (1938) they represent an independent family with genera living all over the world, except in South America.

Genus *Bithynia* LEACH, 1818 (= *Bulimus* SCOPOLI, 1777)

The genus is based on *Bithynia tentaculata* (LINNAEUS, 1758) that lives in Europe. Its protoconch is quite large measuring 0.75 x 0.90 mm with 1.5 whorls (RIEDEL, 1993). It develops within the egg capsule fed by much liquid yolk. There is only one egg in each capsule and young hatch after 2–3 weeks, depending on temperature. The adult shell of *Bithynia tentaculata* consists of 5 to 6 whorls with rounded sides and is 10–12 mm high and 6–7 mm wide, with rounded whorls and calcified operculum (GLÖER, 2002; GRAHAM, 1988). It lives in lakes by collecting organic particles from the bottom with the teeth of its radula and by filtering phytoplankton from the water with its gutter-like gill. The animals live for a year, sometimes even more than two years.
Bithynia is represented by a few species in Europe.

Bithynia syriaca Blanckenhorn, 1897
(Pl. 2/12–17; 3/2–5)

Diagnosis: The shell consists of 4 whorls with evenly rounded whorls and ornament of weak spiral grooves.

Description: The shell consists of approximately 4 whorls and is up to 2 mm high. Its embryonic whorl measures 0.35 mm and consists of a little more than one whorl (pl. 2/15–17). Growth lines appear only on the teleoconch and document the onset of its formation. The whorls of the teleoconch have evenly rounded sides and increase in width only in the first whorl, later remain of the same width to even decrease a little in width in the body whorl (pl. 2/12–17). This shell shape is somewhat pupa-like. The aperture has a thickened margin and its shape is almost round with an angle only in the outer apical edge. Ornament of the teleoconch whorls consists of simple fine growth lines and a very fine pattern of spiral grooves. The inner lip is continuous with the outer lip and there is a small umbilical notch. The body whorl occupies up two thirds of shell height. The outer lip is simple and parallel to the axis of coiling of the shell. The operculum is thick and concentrically lined on the outside with small spiral and eccentric nucleus. The muscle scar is thick, concave, occupies most of the inner surface of the operculum.

Difference: The differences, according to Tchernov (1975a), consist mainly in the fewer whorls (4) in *Bithynia syriaca*, the well rounded body whorl, the presence of very fine spiral grooves. It thus intermediates to a new species that has been suggested by Tchernov (1975a: pl. 2, fig 3) with grooves but in addition also fine axial ribs. It may well be that both species actually represent one and the same with some variability among populations. The living *Bithynia hawaderiana* Bourguignat, 1853, from the upper Jordan and Lake Tiberias (Tchernov, 1975b) has one more whorl.
Bithynia hawaderiana from Lake Tiberias has been described by Tchernov (1975b: figs. 12–13). Accordingly the about 5 mm high and 3 mm wide shell consists of 5 whorls without umbilicus and of pointed conical shape. In the smooth shell the spire occupies about half shell height. Sutures are shallow and the aperture is of oval shape with simple margin that is continuous all around. It has an upper angle and a thickened inner lip that covers a narrow umbilical furrow. The operculum is thick and concentrically lined on the outside with small spiral nucleus.

Remarks: *Bithynia hawaderiana* may be the same species as that named *Bithynia phialensis* (Conrad, 1852) by Schütt (1983). Horowitz (1979) suggested that the species of Lake Kinneret (Tiberias) has been living to the early middle Pleistocene and is the Bithynia from Ubeidiya Formation, while in the Erk el Ahmar the genus was present with *Bithynia syriaca*.
Schütt (1988) considered *Bithynia syriaca* to represent a fossil representative of *Bithynia phialensis*. Schütt (1988: pl. 3, fig. 29) described a *Bithynia applanata* Blanckenhorn, 1897, remarking that it is very similar to the recent species, but is not the same but closely related to the ancestor of the modern form. All these could be the same and they all fall into the varieties of the modern species from Israel.
The embryonic shell from *Bithynia* from Al-Qarn Formation has a similar shape as that of *Bithynia tentaculata* reflecting a similar mode of development and hatching. Young hatch with more than one whorls of embryonic shell that is smooth and growth line appear only at hatching. Thus the hatching is well expressed in shell morphology. The first whorl of the shell is the embryonic shell that was formed before the young snail left its egg capsule crawling and benthic. Shell growth within the egg capsule occurred on an embryo developed beyond the veliger stage and is marked by simple straight lines of growth. The time just at or after hatching is well documented by an increased density of increments of shell growth and by first signs of shell fracturing. This only occurred when the small snail had left the shelter of its egg capsule (Bandel, 1982). The small snail, at that stage of development carried a shell of about 0.75 mm in size.

Gabbiella senaarensis (Küster, 1852) represents *Bithynia* that lives in the Nile near Luxor and in the Nasser Lake, according to Schütt, but is also reported from the lower Nile (Brown, 1980: fig. 41b). It also has four whorls of its shell and is very close in shape to the species from Al-Qarn, but the aperture is more circular in outline. Also *Bithynia leachii* (Sheppard, 1823) (Graham, 1988: fig. 77) commonly occurs together with *Bithynia tentaculata* has not more than 4.5 whorls, rounded aperture and up to 6 mm high and 4 mm wide shell.

Hydrobia cf. *acuta*
(Pl. 3/1)

The shell with 4.5 whorls is 1.7 mm high and almost 1mm wide. Whorls are evenly rounded and smooth with only inclined growth lines as sculptural elements. The relative height–width relation of the whorls changes during growth and older shells appear to be more slender than younger shells. The aperture is evenly rounded and the inner lip simple with no umbilical opening and just a pit at the anterior end of the margin of the inner lip. Only shells of juvenile individuals of this *Hydrobia* like species were encountered, which document their presence in the waters in which Al Qarn Formation was deposited. They lived here only rarely. In the Jordan River that flowed near here before salty Lake Lisan flooded the area and in fresh water ponds in Jordan gastropods with similar shells were encountered and determined by SCHÜTT (1983: fig. 4) as *Paludina musaensis*. According to TCHERNOV (1975a: pl. 1/5) *Hydrobia acuta* that had also been determined as *Hydrobia fraasi* BLANCKENHORN, 1897, was widely distributed since the Neogene in the Mediterranean region of Europe and in Mesopotamia. TCHERNOV determined the species from the fauna of the Lake Erq el Ahmar. Here, it has a 7 mm long and 5 mm wide shell. A *Hydrobia ventrosa* was mentioned by NELSON (1973) to live in the Druze and Shishan pools at Azraq Oasis, and it may be a related species, but according to own observations has a less slender shell. *Hydrobia* and many related members of the Hydrobiidae have different species often with very similar shells (WILKE et al., 2001), and the two incompletely grown shell encountered in Al Qarn Formation cannot be described sufficiently well to determine their species. The structure of the shell has crossed lamellar composition, as is usually present in members of the Hydrobiidae. The shell from Al Qarn Formation is fractured near its margin, and that fracture revealed a well preserved and simple crossed lamellar structure with the aragonitic composition of the shell unchanged.

Genus *Islamia* RADOMAN, 1973

Islamia jordanica n. sp.
(Pl. 2/6–11)

Diagnosis: The embryonic shell is trochispiral and consists of 1.5 whorls with granular ornament. The succeeding teleoconch has 1.5 whorls with rapid increase in width and evenly rounded shape, ornamented only by growth lines. The aperture is rounded with solid margin and inclined position. Shell size is approximately 1 mm wide and high with 0.3 mm wide protoconch.

Holotype, origin of the name and type locality: The individual in pl. 2/8 represents the holotype. It was collected by us at the type locality of the Al Qarn Formation next to King Abdulla Canal in the northern Jordan Valley. The holotype is housed in the collection of the Geologisch-Paläontologisches Institut und Museum, Hamburg University, no. 4710.

Description: The small trochispiral shell consists of only three whorls (pl. 2/7, 8, 11). When fully grown, growth line pattern becomes more irregular and denser as is the case in the juvenile shell. Most of the teleoconchs have simple straight and fine growth lines, but the plane of the aperture is inclined in regard to the axis of coiling (pl. 2/10). The evenly rounded whorls of the protoconch have an ornament that displays a simple and irregularly distributed grain- groove pattern (pl. 2/9). Growth lines appear only near the end of the embryonic shell. Its margin is documented by strong increments of growth and may be thickened (pl. 2/6, 9). During their life time some of the small gastropods had been attacked and had repaired the chipped shell margin again.

Discussion: Among the *Valvata*-shaped Hydrobioidea discussed by BANDEL (2010) a group of species from the Late Miocene and the Pliocene of the Paratethys was described. One determined as cf. *Horatia* from Al Qarn Formation was compared to these (BANDEL, 2010: pl.7, fig. 77). The species from the Al Qarn Formation was interpreted to closely resemble species belonging to the genus *Horatia* since it is very close in shape to a species determined as cf. *Horatia* from the Pannonian of Lake Balaton region in Hungary (BANDEL, 2010: pl. 7, figs. 78–81). Characteristic to both, the species from Al Qarn Formation and its similar counterpart from the Late Miocene to Pliocene of sand pit near Papkesi close to the eastern end of Lake Balaton in Hungary, is also the slight detachment of the body whorl in fully grown individuals. But the species here described from Al Qarn Formation also resembles *Islamia* RADOMAN, 1973, that is distributed from the Iberian Peninsula around the Mediterranean with somewhat spotty distribution. *Islamia* usually has a more highly coiled shell and is based on *Islamia servaini* (BOURGUIGNAT, 1887) (= *Islamia valvataeformis* (MOELLENDORFF, 1873)) that lives in the southern Balkan area. A cf. *Islamia* was also noted to occur in the Pannonian and Pontian lake deposits of the area of modern Lake Balaton in Hungary, and is very similar to the here described species.
BODON et al. (2001) have reviewed this group of small sized gastropods. These species have a shell shape as is found among the living genera *Hauffenia*, *Islamia*, *Heraultia* and *Horatia* (BODON et al., 2001). *Horatia* BOURGUIGNAT, 1887, has basically the same characters of the shell (BODON et al., 2001), but with the shell a little higher in the type species *Horatia klecakiana* BOURGUIGNAT, 1887, and the protoconch of the same

ornament. The protoconch of *Heraultia* BODON, MANGANELLI & GIUSTI, 2001, is very close in shape as that of Pannonian deposits (BANDEL, 2010: pl. 6, fig. 70).
Among living species of this group of genera with rather similar shell shape the anatomy is regarded the most important characters defining the living species besides the shape of the shell. The shape of the genitalia distinguishes species and all four genera are considered related to the Hydrobiidae and belong to the subfamily Belgrandiinae. The mode of development of *Horatia*, *Heraultia*, *Islamia*, and *Hauffenia* is from yolk-rich eggs. Young snails hatch in the crawling stage and with a shell of about 1.5 whorls of trochispiral coiling mode and an ornament by small pits and ridges in irregular orientation or arranged to form spiral ribs as had been noted also by BINDER (1967).
For the new species from Al Qarn Formation the genus *Islamia* was selected since its type species is living in the SE Mediterranean region in fresh water lakes and in age comes close to the Jordanian fossil snail.
Regarding the life habits of *Islamia* and relation little is known. The shape of the protoconch indicates hatching from an egg mass as crawling young, and the small size of the gastropod feeding on small particles.

Cerithimorpha

Family Thiaridae TROSCHEL, 1857

Genus *Melanoides* OLIVIER, 1804

Melanoides has the type species *Nerita tuberculata* MÜLLER, 1774, that was originally described from SE India. This species is widely distributed in running and standing fresh water of warm countries. The medium sized to large snails have an up to 5 cm long shell with high and slender spire that may consist of 10 to 15 whorls of which the early ones are often decollated. Both transverse and spiral sculpture is present, commonly ribs form tubercles at crossing.
The morphology of the protoconch in *Melanoides* reflects the mode of early development. Eggs held in a thin egg capsule are collected in a brood pouch. Here the young hatch and feed on particles which are provided by the brood pouch. First they collect them with a velum. Later they discard the velum and carry out metamorphosis to adult body organization, but still feed by particles provided by the brood pouch. The embryonic part of the shell is only subsequently mineralized and of irregular shape, while the post-metamorphic shell has regular shape and ornament. Hatching from the brood pouch occurs when several whorls of the shell have been completed and the young have the shape and organization of miniature adults.
Similar shapes in the early ontogenetic shell have been recognized among gastropods that lived in coastal swamps of the Tethys Ocean during the Middle Eocene in localities which are now in Hungary (Dudar). Here BANDEL & KOWALKE (1997) noted that a potential ancestor living in the Eocene called *Melanotarebia* BANDEL & KOWALKE, 1997, had a protoconch that indicated a similar ontogeny as found among modern Thiaridae such as *Melanoides* and *Tarebia* with young developing in a brood pouch. BROWN (1980) suggested that in addition to the type species, in Africa more than 30 species of *Melanoides* can be found, most of them in the Congo-Basin. *Melanoides tuberculata* is found in Lake Malawi with individuals which are just as is characteristic to the species but also individuals differing more or less strongly from each other, but BANDEL (1998, see here references) found many transitions between individuals which have the characters of some of these recognized species.

Melanoides abuhabili n. sp.
(Pl. 2/12–14)

Diagnosis: *Melanoides abuhabili* differs from *Melanoides tuberculata* (MÜLLER, 1774) that is living in the Jordan Valley (pl. 2/15) by characters of the first whorls of the teleoconch. They are ornamented by two spiral ribs crossed by axial ones, these in the first whorl of the teleoconch are close to each other and weak, while on the second they are placed more distant to each other and of the same strength as the spiral ones and in the third whorl the axials are even more distant. Approximately 30 axial ribs feature the first whorl, approximately 20 are on the second whorl of the teleoconch and the third has about 12. In case of *Melanopsis tuberculata* more than 40 axial ribs feature the first three whorls of the teleoconch and later axial ribs become dominant while the lateral ones decrease in size. The reticulated ornament of the first whorls of the teleoconch thus changes to an axially ribbed ornament.

Holotype, origin of the name and type locality: The individual in pl. 2/13 represents the holotype. It was collected by us at the type locality of the Al Qarn Formation next to King Abdulla Canal in the northern Jordan

Valley. The holotype is housed in the collection of the Geologisch-Paläontologisches Institut und Museum, Hamburg University, no. 4711.

Description: *Melanoides abuhabili* has the embryonic first whorls with irregular shape as is characteristic to *Melanoides tuberculata* as well. The early whorl of the teleoconch has reticulate ornament of the first whorl with many fine axial ribs and two spiral ribs. In the second whorl of the teleoconch a pattern with axial and spiral ribs of similar strength forms a reticulate ornament. The later whorls of the teleoconch continue with a widely reticulate ornamental pattern, but whorls beyond the fourth whorl of the teleoconch have not been encountered, and only 4 specimens of the new species are present. The apical angle is approximately 40° while that of *Melanopsis tuberculata* has around 30°.
In the living *Melanoides tuberculata*, as they also are present in the King Abdulla Canal next to the outcrop of Al Qarn Formation, the first three whorls of the teleoconch have a densely reticulate pattern and the wider ornament with axial ribs becoming dominant appears only within the fourth whorl of the teleoconch.

Discusssion: *Melanoides abuhabili* from Al Qarn Formation occurs rarely. It resembles closely the modern *Melanoides tuberculata* that lives in muddy places of creeks, and periodically in large numbers in Karama Reservoir when water is not very salty and also lived in the large shallow lakes which were present at Azraq Oasis.
From Erq el Ahmar Formation, TCHERNOV (1975a: pl. 2, fig. 7) documented a species called *Melanoides dadianus* OPPENHEIM, 1918, that had been founded based on individuals from the Neogene of Asia Minor. In the specimen from Erq el Ahmar the early part of the shell is not present, and thus it may represent the same species that is here described as *Melanoides abuhabili*. TCHERNOV (1975a: pl. 3, figs 1–2) also documented a *Melanoides tuberculata* from Erq el Ahmar, which also does not show the early formed shell. In case of this being the same species as that living in Lake Tiberias, as was assumed by him, it is also not *Melanoides abuhabili*. A third *Melanoides jordanicus* TCHERNOV, 1975, has weak ornament and thus differs as well. TCHERNOV (1975a) noted that the adult shells of *Melanopsis jordanicus* and *Melanopsis dadianus* are less slender than *Melanopsis tuberculatus*, which relates them to *Melanopsis abuhabili*.
HELLER & EHRLICH (1995) noted the tolerance of *Melanopsis tuberculatus* of Israel to polluted water. *Melanoides tuberculatus* is a parthenogenetic species and thus large population consist only of females. A single individual can start a whole new generation. Rarely also males occur as has been recognized from individuals living in the region by LIVSHITS & FISHELSON (1983) and recognition of males and females were confirmed by HELLER & FARSTAY (1989, 1990) from Israel.
Melanoides tuberculata lived in the late Pliocene of Kos (WILLMANN, 1981) and at the same time in Rhodos. In the Nile and especially the many irrigation channels connected to it in Egypt *Melanoides tuberculata* lives in masses and represents one of the most common gastropods present in modern Egypt (SCHÜTT, 1983: fig. 8, own observations). In Jordan *Melanoides tuberculata* prefers muddy ground in the very shallow water of lake margins or in puddles next to running water.

Family Melanopsidae H. & A. ADAMS, 1854

Genus *Melanopsis* FÉRUSSAC, 1807

The type to the genus is *Buccinum praemorsum* LINNÉ, 1758, from fresh water rivers and springs in southern Spain, and the Maghreb (BANDEL, 2000). The shell has a cyrtoconoid outline with the body whorl more or less inflated. Whorls of the spire are hardly rounded and smooth or ornamented by axial and/or spiral ribs. The size ranges from about 1 to 4 cm in shell height. The aperture is depressed egg-shaped with a regular rounded outer lip, anterior channel, and a smooth inner lip which is usually thickened by a posterior callus pad. There is no umbilicus.
The young hatch when they have developed to the crawling stage and with a shell that measures 0.2–0.4 mm in diameter. They grow up within eggs which are distributed on the bottom substrate one by one or are glued to hard substrates, also onto the shells of fellow *Melanopsis,* and are difficult to detect since they are covered with mucus which collects particles swimming in the water or from the ground.
The oldest representatives of *Melanopsis* known from Jordan are the ones found in Al Qarn Formation (BANDEL, 2000; BANDEL et al., 2007). They resemble the species of *Melanopsis* which live in Jordan but also have some characters of species which have been described from Pliocene in lakes connected to the Paratethys (now they are exposed, for example, on Kos Island; see WILLMANN, 1981).
Living *Melanopsis* in Jordan is often attacked by the crab *Potamon* which can crack the shell beginning at its aperture. This or a very similar crab also lived in the waters in which the Al Qarn gastropods occurred (pl. 1/3–4), as is documented by their preserved claws.

The operculum of *Melanopsis* is organic and not as protective as the calcareous one of *Theodoxus*. Still *Melanopsis* represents the most remarkable gastropod found in running fresh-water in Jordan. In a clean stream individuals may be very common and may sometimes be found on each pebble in the stream bed.
Of the four *Melanopsis* species described from Al-Qarn Formation by BANDEL et al. (2007), two have been considered to be extinct (*Melanopsis aaronsohni, Melanopsis tchernovi*) whereas two have been interpreted to still occur in the Levant (*Melanopsis buccinoidea*, *Melanopsis costata*). The *Melanopsis costata* as suggested by BANDEL et al. (2007) may also be interpreted to represent two species, one with a distinct shoulder besides the rounded axial ribs, and the other without such shoulder and rounded sides of their whorls (pl. 2/18). Regarding the general shape of their shell both varieties resemble *Melanopsis buccinoidea* (pl. 2/20, pl. 3/1) that has rounded and smooth whorls and *Melanopsis tchernovi* (pl. 3/2) with a similar shoulder but otherwise smooth shell without ribs.
The 5 species which can thus be distinguished may well be closely related to each other and to *Melanopsis costata* OLIVIER, 1804, as it lives in Jordan and has slender fusiform shape and may consist of up to ten whorls and reach a size of up to 3.3 cm in height (for example as lived in Azraq Druz in a pond before it was destroyed 1995), and to *Melanopsis buccinoidea* that is common at many places in Jordan. In case of *Melanopsis costata* ornament consists of 12 to 15 rounded ribs in an even curve onto the rounded the base. Ribs are usually continuous onto the base but may become less distinct here. *Melanopsis buccinoidea* FÉRUSSAC, 1823, has a smooth shell with approximately 8 whorls and size of around 2.5 cm in height. The size of the whorls increases in width in a regular way and the suture between them is shallow (it is quite like the individuals found nowadays living in several creeks in Jordan and in the rivers Mujib and Al Hasa).
Melanopsis aaronsohni BLANKENHORN & OPPENHEIM, 1927, has a fusiform shell of at least eight whorls. It is ornamented by axial ribs from the fourth whorl onwards. This species from Al Qarn Formation is considered to be the same fossil species as that from Erq el Ahmar that is preserved in the collection in the Hebrew University at Jerusalem. *Melanopsis tchernovi* HELLER & SIVAN, 2002, has a shell with approximately 8 whorls of which the first five are conic with flattened sides (pl. 3/2). The shell of *Melanopsis tchernovi* may be more than 17 mm high with the first 5 whorls conically coiled with flattened sides and the sixth develops a shoulder. *Melanopsis tchernovi* was first described from Erq el Ahmar by TCHERNOV (1975a: pl. 2, fig. 6) as *Melanopsis* cf. *doriae* ISSEL, 1866, and BANDEL (2000, figs. 139–142) determined this species as *Melanopsis dufouri*.
Even though the similarities among these species from the Jordan Valle and the general region of the Levant and also the transitions observed between them and later living species have been interpreted to represent independent species (HELLER & FARSTAY, 1999; HELLER et al., 1999; HELLER & SIVAN, 2001, 2002a, b; HELLER et al., 1999, 2005) it also document that *Melanopsis* is a rather special genus. BANDEL (2000) studied many species of this genus especially such which had been living in the depositional environment of the Paratethys and suggested that in the development of species groups which are interconnected by their morphology interbreeding between species that had been a character of the genus since long ago. When the species which now live in Jordan are interpreted in this respect it becomes evident that interbreeding is still going on. Thus the many species of *Melanopsis*, fossil and recent, which have been described from Jordan and Israel, are interconnected by transitional individuals but typical representatives of a species may also be encountered in large numbers or even exclusively in their living environment. In case of the species from Al Qarn Formation four species can be picked out with a good number of characteristic individuals, while *Melanopsis aaronsoni* occurs only with fewer numbers of individuals.

Melanopsis salamei n. sp.
(Pl. 1/9–11; 2/16, 17, 19; 3/3)

Diagnosis: The last 4–5 whorls of the teleoconch are ornamented with strong axial ribs and have a shoulder below the suture and the ribs may form a node at its edge. The juvenile shell in contrast is smooth and without shoulder (pl. 2/16, 17, 19; 3/3) up to the fifth whorl. The shape of the shell changes after three juvenile whorls with smooth surface and straight suture to one with axial ornament in the fourth whorls and strong ornament and angular shape only in the fifth whorl. The shell with 8 whorls may be 3 cm high.

Holotype, origin of the name and type locality: The individual in pl. 1/11 represents the holotype. It was collected by us at the type locality of the Al Qarn Formation next to King Abdulla Canal in the northern Jordan Valley. The holotype is housed in the collection of the Geologisch-Paläontologisches Institut und Museum, Hamburg University, no. 4712.

Description: *Melanopsis salamei* had been placed with *Melanopsis costata* "stepped" in BANDEL et al. (2007: fig. 3) and was determined as *Melanopsis orientalis* in BANDEL (2000: figs. 104, 107–110). But these individuals can also be interpreted to represent an independent species since it differ as much from *Melanopsis costata* as the species determined as *Melanopsis tchernovi* differs from *Melanopsis buccinoidea*, that is by the presence of a shoulder below the suture (compare pl. 3/1 with pl. 3/2).

Difference: *Melanopsis salamei* differs from the similar *Melanopsis paraecursor* SCHÜTT & ORTAL, 1993, as described by HELLER & SIVAN (2002a) from Erq el Ahmar by having a less dense pattern of ribs. As was noted by HELLER & SIVAN (2002a) *Melanopsis multiformis* BLANCKENHORN, 1897, is also of similar shape, but its shell has a broad tubercle in the upper part of each rib and there are more ribs on each whorl.
Melanopsis obediensis PICARD, 1934, from the Pleistocene deposits of Ubeidiya is similar (PICARD, 1934: pl. 7, figs. 30–44), but has a shorter and more rounded shell (HELLER & SIVAN, 2002b: figs. 3 E–G). Species from the *Melanopsis costata* group still living in Jordan have no stair-like spire. Also similar is *Melanopsis multiformis* BLANCKENHORN, 1897, from the Pliocene of the mid Orontes area regarding shell shape, but as the species name indicates, the shape of individuals that had been placed here by BLANCKENHORN (1897) could also be interpreted to hold a number of different species.

Heterostropha FISCHER, 1885 / Heterobranchia GRAY, 1840
Superfamily Valvatoidea GRAY, 1840

Fresh water Valvatidae are united with marine Cornirostridae in the superfamily Valvatoidea of the Heterostropha (= Heterobranchia according to HASZPRUNAR, 1985). When WENZ (1938) discussed the Valvatidae he knew only members of the *Valvata* relation which live in fresh water. He interpreted them to form the superfamily Valvataceae that had its species restricted to the Northern Hemisphere. PONDER (1990, 1991) discovered relatives of *Valvata* living in the sea grass environment of the tropical seas for example of Australia, and called them Cornirostridae. Marine species with similar characters of their shell as those living in the sea today have been recognized in deposits as old as Devonian (BANDEL & HEIDELBERGER, 2002). Apparently the transition of members of this relation within the Heterostropha from the sea to the environment of fresh water occurred during the time of sea regression from Central Europe at the end of the Jurassic (BANDEL, 1991).
The shell of members of the Valvatidae is usually small, trochiform to discoidal, often smooth, but may also be variously ornamented. Here the adult shell (teleoconch) is coiled to the right (dextral) while the shell formed by the embryo in the shelter of the egg case has a slight twist to the left (sinistral). In case of the relatives of this group which live in the sea, the Vitrinellidae BUSH, 1897 = Cornirostridae PONDER, 1990 have the left mode of coiling (sinistral) of the early ontogenetic shell well developed as is seen in case of two species of that group which live in the Gulf of Aqaba in the shallow water near the Jordanian Marine Station. Here *Vitrinella urdunica* BANDEL, 2010 and *Tomura aqabaensis* BANDEL, 2010 have a protoconch that is composed of the embryonic shell coiled to the left, a larval shell in which this coiling mode changes to plane coiling and the teleoconch is than coiled to the right (BANDEL, 2010: pl. 1, figs 11–12, pl. 2, figs 15–17).
In case of *Valvata*, living in fresh water, a larval shell is not developed and the embryonic shell that here occupies the whole protoconch has secondarily become almost planispiral (Riedel, 1993). Regarding the soft body *Valvata,* as well as its relatives living in the Gulf of Aqaba, has several distinctive features of its anatomy. The gill, for example, and a pallial tentacle are characteristic (RATH, 1988). In contrast to other small gastropods the cilited branches of the gill are usually exposed in front of the aperture, when the animal is active.

Family Valvatidae GRAY, 1840 (= Valvatidae THOMPSON, 1840)

Genus *Valvata* O.F. MÜLLER, 1774

The shell is trochiform to discoidal, variously ornamented with a protoconch in which the embryonic shell coils in a weakly left mode while the succeeding teleoconch coils to the right (RIEDEL, 1993; BANDEL & RIEDEL, 1994). The teleoconch consist usually of a small shell that is lowly trochispiral to plane in shape with open umbilicus with few rounded whorls that may be smooth or bear spiral lirae or more rarely spiral ribs. The aperture is round and can be closed by a multispiral round operculum with central nucleus and construction of organic material. The protoconch of *Valvata piscinalis* has ornament of very fine spiral ribs and crossing collabral lines.
WENZ (1938, fig 1320) based the genus on *Valvata cristata* MÜLLER, 1774 with smooth rounded whorls, about 3 mm and low shell which is common in ponds and lakes in Europe. According to GRAHAM (1988) the genotype is *Nerita piscinalis* MÜLLER, 1774, a species with higher shell.

Valvata cristata MÜLLER, 1774
(Pl. 3/4–7; 4/13–15)

Of the two species of *Valvata* recognized from Al Qarn Formation, one with almost plane shell here determined as *Valvata cristata* is known in Jordan only from the fossil fauna, while the other with higher shell determined as *Valvata saulcyi* was still found alive in a creek and spring at the Wadi Rum in southern Jordan (SCHÜTT, 1983: fig. 2).
The species from Al Qarn Formation that is close in shape to *Valvata cristata* has a maximum diameter of the fully grown shell of a little less than 2 mm and with 3.5 whorls almost in one plane with flattened apical side and wide umbilicus on the base. The whorls meet only at their periphery and the aperture is circular and inclined.
Individuals of *Valvata cristata* described by BANDEL (2010: figs. 40–46) from lakes in Romania and Hungary have exactly the same shape as the species encountered in Al Qarn Formation. The embryonic shell measures approximately 0.35 mm in diameter and consists of a little more than one whorl. Its apical end is slightly twisted to the left and thus extends from the umbilical side of the teleoconch. An ornament of fine spiral lines covers the embryonic shell and ends in the transition to the teleoconch with growth lines appearing. While these are straight in the protoconch, they become inclined in the teleoconch reflecting the inclined shape of the aperture of the teleoconch during its growth. When *Valvata cristata* approaches the final stage of its shell growth increments of growth are more prominent than those that have formed on the teleoconch before. Among the gastropods from the Al Qarn Formation the shell of *Valvata cristata* in size and shape resembles that of *Gyraulus*. The later displays much variability as is described below, but can be distinguished from the shell of *Valvata* by the character of of its coiling mode that is more trochospiral in *Gyraulus*, by the coiling of the embryonic whorl that is more clearly sinistral in *Valvata*, by the increase in shell width that is more rapid in *Gyraulus* (see figures in plate 4). When these characters are taken into account even shells with a not perfect preservation can be distinguished from each other and recognized a belonging to one or the other species.

Valvata saulcyi BOURGUIGNAT, 1853
(Pl. 3/9–11)

Valvata saulcyi is still found living in the region was a very common species in the lake in which Al Qarn Formation formed (BANDEL, 2010: figs. 52–53). Its presence represents evidence of a deposition of the fossil bearing sediments in a lake rather than running water.
Valvata saulcyi has a trochiform shell that consists of three to 3.2 whorls with a little more than 2 mm in diameter. The fossil species has the same trochiform shell shape and consists of approximately three whorls with 2.2 mm in diameter. The protoconch can be divided in two portions, a initial one with 0.2 mm in diameter without growth lines and a well developed ornament of fine ridges and grooves and notable weakly left coiled shape and a second part with growth lines included in the ornament up to the increase of growth lines (pl. 4/10). These mark the margin of the embryonic shell which is approximately 0.4 mm in diameter and consists of slightly more than one whorl (pl. 4/10, 13).
Valvata saulcyi from Lake Al Qarn thus hatched from its egg mass with a larger embryonic shell than that present in *Valvata cristata* when it left its egg case. In such cases, when the embryo after hatching had at first problems of continued growing, the protoconch and succeeding teleoconch could deviate in the mode of their coiling which can be seen on some individuals as change of the coiling mode in the embryonic shell in regard to that of the teleoconch (pl. 4/8, 5/15).

Remarks: The living species of *Valvata saulcyi* had been encountered in a spring in Wadi Rum, in the Roman bath-pond at Jerash in 1978 and in the southern pool that existed in Azraq oasis at that time (SCHÜTT, 1983: fig. 2). But neither near Jerash nor in the pool of Azraq living individuals of *Valvata* can still be encountered (2011–2013).
HOROWITZ (1979) noted *Valvata* species at "modern" Lake Hula and in the fossil deposits of Ubeidiya and Erk el Ahmar Formations. SCHÜTT (1983) suggested that this species represents the replacement to *Valvata piscinalis* in the area of Syria and south of it. TCHERNOV (1975: pl. 1, fig. 4) suggested that *Valvata saulcyi* represents the only species that lived throughout the Neogene and Pleistocene of the Levant. He also found that the *Valvata saulcyi* lives in the Jordan River flowing into the lake, but not in Lake Tiberias itself.
SCHÜTT (1988: pl. 3, fig. 26) described a variety from the Pliocene of the Orontes valley as *Valvata saulcyi pliocaenica*. TCHERNOV (1975a: pl. 1, fig. 4) found *Valvata saulcyi* to represent the only species that lived throughout the Neogene and Pleistocene of the Levant. He also suggested that it had been determined as *Valvata cristata* by BLANCKENHORN (1897). *Valvata nilotica* JICKELI, 1874, from the Nile was described as closely resembling the *Valvata saulcyi* (BOURGUIGNAT, 1853) from Syria as was confirmed by BROWN (1980: fig. 31). While the shape of the shell of the species from the Nile is very close to that of *Valvata* from Al Qarn Formation,

the size of *Valvata nilotica* reaches 3 mm in height and 4 mm in width according to BROWN (1980) but he also noted that specimens are usually smaller. As stated by Schütt, the European *Valvata piscinalis* has a higher shell (BANDEL, 2010: figs. 47–49).

Pulmonata Basommatophora

The Basommatophora are shell bearing pulmonates of the fresh water without operculum and one pair of tentacles on their head which bear eyes near their base. The early ontogenetic shell is of simple shape and ornament since there exists no larval stage in the plankton during the development and a miniature adult usually leaves the egg capsule after embryological development (BANDEL, 1982; RIEDEL, 1993). That portion of embryological development during which the shell and mantle are in close connection to each other and the shell is attached to the shell secreting epithelium is only short and ends with the formation of a shallow initial shell disk.

Superfamily Lymnaeoidea, family Lymnaeidae RAFINESQUE, 1815

Members of that group of gastropods living in fresh water have a spirally coiled shell or, sometimes a cup-like shell. The genera *Galba* SCHRANK, 1804, *Bulinus* O.F. MÜLLER, 1781, and *Physa* DREPARNAUD, 1801, have species which live in Jordan (SCHÜTT, 1983: figs. 10–12). HUBENDICK (1970) expressed the opinion that there are only about 50 valid species within this family alive today, but about 1200 species have been described.
Lymnaeidae have no gill but transport a bubble in their pallial cavity, as is also the case in members of the Physidae. They can thus also utilize poorly oxygenated water by taking their oxygen with them. In *Galba* the bubble is actively sucked into the cavity guided by the muscular opening, the (pneumostom) and it is also expelled that way by being pressed out due to muscular contraction of the walls of the lung.

Genus *Galba* SCHRANK, 1804
(Pl. 3/15–20)

The small shell with pointed spire is conical and sutures between whorls are deep. Shell resembles that of *Stagnicola*. The type *Galba truncatula* (O.F. MÜLLER, 1781) (*Buccinum*) = *Galba pusilla* SCHRANK, 1803, is from central Europe. When encountered alive in Jordan the shell can be about 8 mm high and 3.5 mm wide (SCHÜTT, 1983: fig. 11). The species was determined as *Lymnaea (Galba) truncatula* (O.F. Müller, 1781) and resembles that found in Al Qarn Formation. Here it is represented by 5 individuals all of which represent juvenile shells that have grown to a maximum size of almost 3 whorls and a height of 2.5 mm. The small shell with pointed spire is conical and sutures between whorls are deep. The aperture is a little higher than the spire. The outer lip of the aperture is thin and evenly curving and the inner lip is reflexed over the surface of the whorl below. The embryonic whorl measures approximately 0.5 mm and grades evenly into the teleoconch separated from it only by the appearance of distinct growth lines on the margin to the first whorl of the teleoconch. The protoconch is smooth and represents the embryonic shell which was formed within the egg mass before hatching.
Lymnaea lagotis (SCHRANK, 1803) as described by TCHERNOV (1975a: pl. 3, fig. 4) from Erq el Ahmar Formation cannot be distinguished from the "*Galba*" from Al Qarn Formation. HOROWITZ (1979) noted this species or a very similar one also from Ubeidiya Formation and from Erk el Ahmar Formation. *Galba truncatula* occurs in Europe as well as Africa (BROWN, 1980: fig. 76d).
Galba can be interpreted to represent a subgenus of *Lymnaea* LAMARCK, 1799. Among the basommatophorans resembling the lymnaeid *Galba* in regard to the shape of their shell, a member of the genus *Physa* and one of *Bulinus* are found living in Jordanian waters.

Family Planorbidae RAFINESQUE, 1815

Genus *Gyraulus* CHARPENTIER, 1837

The genotype is *Planorbis albus* O.F. MÜLLER, 1774, which represents a very common fresh water snail found in many European lakes and ponds. The left coiled (sinistral) or plane shell may be convex or plane on the upper side and has a concave lower side (umbilicus). The sculpture consists of growth lines which are crossed by delicate spiral lines. The rounded aperture is high and inclined. Some groups deflect the last whorl near the aperture. Growth is allometric since individuals are proportionally high in youth and become proportionally lower during growth (WENZ & ZILCH, 1960). On embryonic shells spiral striation occurs in most species of *Gyraulus* and also those of *Anisus*, and *Planorbis* (WALTER, 1962; RIEDEL, 1993). The protoconch of *Gyraulus* resembles that of *Valvata* in shape and ornament. In contrast to *Valvata* its margin is not straight but inclined, and increase in shell diameter is a little more rapid (BANDEL, 2010: figs. 177, 179, 187).

Gyraulus cf. *piscinarium* (BOURGUIGNAT, 1852)
(Pl. 4/1–12)

Gyraulus piscinarium (BOURGIUGNAT, 1852) with small planispiral shell and flattened apical side and the umbilical side concave and with rounded whorls was determined from Jordan. It was described by SCHÜTT (1983: fig. 14) as *Gyraulus piscinarium homensis* (DAUTZENBERG, 1894). It was collected 1978 from a spring that issues from the base of the Cambrian Sandstones where they rest on the crystalline base at Wadi Rum and the shells were described by SCHÜTT (1983: fig. 14).

Gyraulus from Al Qarn Formation cannot be distinguished from the individuals found living in Jordan. Its shell is coiled in a plane spiral, consists of 3 whorls with inclination of the aperture indicating dextral coiling mode (BANDEL, 2010: figs. 178–181). The individuals from Al Qarn Formation have rather variable shape and ornament, but closely resemble those of the individuals that had been collected living in ponds in southern Jordan of the Wadi Rum area.

Gyraulus from Al Qarn has the shell up to 3 mm wide, mostly less, and can be approximately 1.5 mm high. It has a rapid increase in shell width, more so than would be the case in *Planorbis*. The embryonic whorls measures approximately 0.35 mm in diameter and consists of a little more than one whorl. Its initial part when seen on the apex of the fully grown shell is dipping slightly below surface, indicating a weak left-hand coiling in the initial part of the embryonic shell, while later parts of the protoconch are coiled in one plane. Ornament of the embryonic shell consists of fine spiral lines of which approximately ten are seen on the exposed protoconch (pl. 4/3, 7, 9). This spiral ornament weakens when approaching the initiation of growth lines on the embryonic whorl. Spirals end when the growth lines are increased in density.

The growth line concentration is indication of the time of shell growth when the young is ready to leave its egg mass and start life as benthic snail.

Growth lines are the ornament of the teleoconch and they have a curving outline on the convex apical side and a straighter one on the concave umbilical side. This pattern reflects the outline of the aperture that lies on the right shell side and is inclined in regard to the central axis of coiling of the shell (pl. 4/1, 4).

Among the individuals encountered at the locality and marly layer that holds the fossils in good preservation shell may differ in regard to the size and shape of the embryonic whorl. It can be slightly smaller and its ornament can be less well developed and also spiral lines may form a denser pattern. Usually the apical part of the shell is evenly convex, but in some cases initial coiling of the teleoconch is irregular and the first whorl of the teleoconch is slightly detached from the second whorl of the teleoconch (pl. 4/4, 11)

Also the embryonic whorl may lie inclined in the apex and a twist in shell coiling occurred when the young had just hatched from its egg case (pl. 4/11). Also varieties may have a higher shell than usual and sutures between whorls can be deeper than is the case in normally coiled shells (pl. 4, figs 4, 11). Also growth line pattern on the teleoconch can be weak (pl. 4/6), usually it is distinct, and in some cases fine growth lines change with stronger ones (pl. 4/10).

If one wanted, the variable shell shape encountered in the fossil population of *Gyraulus* could be used to distinguish several species. They could be separated from each other by the shape of the teleoconch differing among individuals by general shell-shape, such as high versus low or tightly coiled versus coiled in a more detached mode of its whorls. Also shells differ in regard to the ornament some with fine regular pattern others with coarse and sometime even scale-like growth lines (pl. 4/12). Also the embryonic shell could be used to distinguish species in regard to the number of spiral lines on them and their size that ranges between 0.3 and 0.4 mm.

Since all shells have been extracted from a single unit of less than 1 m in thickness with obviously the same composition of species of *Melanopsis* and *Valvata*, it appears that the *Gyraulus* living here together with them survived well but had problems during their shell growth. This could be due to a higher content of dissolved carbonate in the water than was optimal for *Gyraulus*, while the other gastropods that lived here show that the salinity probably was close to normal.

Remarks: Shells resembling those of *Gyraulus* are present from Lower Jurassic onward with very similar shape, size and ornament (BANDEL, 1991; BANDEL & RIEDEL, 1994). Among these fossil species for example *Gyraulus loryi* (COQUAND, 1855) from the Weald (Jurassic-Cretaceous transition) has the same shape of its shell and the same type of micro-sculpture of its protoconch as present in living species. HOROWITZ (1979) determined *Gyraulus piscinalis* from the Ubeidiya and Erq el Ahmar Formations. Also members of *Anisus* STUDER, 1820, with very low shell that has its lower side almost straight and plane and consists of 5–8 whorls with shell size about 10 mm and was determined by HOROWITZ (1979) as *Anisus spirobis.* He also determined a *Segmentina nitida* in these deposits.

Since *Gyraulus* from Al Qarn Formation is represented by a number of shells with rather variable shape these determinations from Ubeidiya and Erq el Ahmar should perhaps be rechecked and confirmed.

MEIER-BROOK (1983) described the shell of the type species of *Gyraulus*, *Gyraulus albus* (MÜLLER, 1774) as having its planispiral shell with 4–7 mm in maximum diameter when fully grown and 1.2–1.8 mm in height with 3.5 to 4.25 whorls. Thus, these differ quite a lot among individuals of the same species. Whorls are equally rounded, embrace one another only a little and have rarely a trace of an angle. The shell is slightly concave on the upper side and deeply concave of the lower side. Growth lines are curving and crossed by fine spiral lines and thus forming a reticulate surface sculpture which is only more or less well developed.

Gyraulus albus and *Gyraulus laevis* (ALDER, 1838) do usually not produce an angle on their shell margin. MEIER-BROOK (1983) found that *Gyraulus albus* regarding shell shape resembles *Gyraulus laevis* closely and without the soft body present both species cannot be kept apart and also that *Gyraulus laevis* and *Gyraulus albus* live commonly together in the same water body more or less at the same spot.

Also *Gyraulus rossmaessleri* (AUERSWALD, 1851) with its shell not larger than 4 mm in width and 1.3 mm in height is similar to *Gyraulus laevis* in shape, but has a flatter umbilicus. *Gyraulus acronicus* (FERUSSAC, 1807) reaches 7 mm in shell diameter and more than 2 mm in height and has up to 4.7 whorls. It is not deeply umbilicate, the sutures are not deep and whorls are flattened and this species coexists with the other members of *Gyraulus*. *Gyraulus riparius* (WESTERLUND, 1865) shells do not exceed 2.3 mm in shell diameter and 0.6 mm in height with its three whorls flattened and angled, and *Gyraulus crista* (LINNAEUS, 1758) has similar shell diameter but is a little higher and also has rapidly increasing whorls with flattened top and rounded base and angled upper side. Here the last whorl does not embrace the penultimate whorl but is loosely attached to its upper side.

Among the European species of *Gyraulus* intermediate shell characters are present between all these species while anatomy can distinguish them clearly. Also individuals of the genus *Armiger* HARTMANN, 1843, closely resemble those of *Gyraulus*, have similar anatomy (GLÖER & MEIER-BROOK, 1998), but the shell has more ornament of growth lines and a more flattened whorl flank (WENZ & ZILCH, 1960: fig. 362). Among the species that can be placed with *Gyraulus* from Al Qarn Formation several resemble *Armiger crista* (LINNÈ, 1758) as it occurs in Europe and North Africa with the shell up to 3 mm wide and 0.9 mm high with almost 3 rapidly increasing whorls with flattened top and rounded base. Here usually the last whorl detaches and whorls are traversed by ridges.

The shells of *Gyraulus* from Al Qarn Formation document quite a lot of variation regarding their shape. Since their anatomy can no longer be determined the species that has been recognized as living in Jordan was used for determination. The shells found from Al Qarn Formation could be placed among several of the living European species of which some are regular other more irregularly coiled, some have stronger growth lines than others, and their final whorl may detach or not. Thus they are here regarded as variations in shell shape due to environmental stress within one species determined as *Gyraulus piscinarium* as had been suggested by SCHÜTT (1983: fig. 14) to the individuals which still live in Jordan.

Limpet-like Planorboidea RAFINESQUE, 1815

Ancylidae and Ferrissiidae according to WENZ & ZILCH (1960) are very similar small limpets. All species included here are of small size and live below water surface. The small limpet has its living environment in areas with moving fresh water, either in streams or at the wave washed shore of lakes. WENZ & ZILCH (1960) interpreted the limpet-like Ancylidae to have developed from the Planorbidae and suggested that the oldest fossils belonging to that group are from the Oligocene of Europe, but BANDEL & RIEDEL (1994) described fresh water gastropods from the Late Cretaceous Santonian of Hungary at Ajka with characters of the shell closely resembling those of modern *Ancylus*. Thus limpet-like Planorboidea among the basommatophorans have been living in the fresh water environment since Cretaceous times.

The genus *Ancylus* O.F. MÜLLER, 1774, has members in Europe and circum-Mediterranean. They occur predominantly in small streams and here are attached to objects, often stones, preferably their lower sides. *Ancylus* is not found in the Nile province (BROWN, 1980), but the very similar *Ferrissia* is here present. The shell of *Ferrissia* WALKER, 1903, has the same shape as is found in *Ancylus* and BROWN (1980) reported several species to occur near Alexandria in the Egyptian Nile. *Ancylus* is based on *Ancylus fluviatilis* MÜLLER, 1774, of which the protoconch was studied from a creek in southern France as well as from similar environment in northern Germany (own data). Its cap-like shell has the apex in posterior position and the adult shell is ornament by fine radial ribs. The embryonic shell has a reticulate ornamental pattern and a depression in its center as has also been documented by BROWN (1980: fig. 79c). *Acroloxus* BECK, 1837, based on *Acroloxus lacustris* (LINNÈ,

1758) has a similar shell but with smooth surface and with the embryonic shell only with a ornament of simple axial ribs (RIEDEL, 1993).

BLANCKENHORN & OPPENHEIM (1927) report of an *Ancylus lacustris* that was found in gravel deposits of Yarmouk River. The protoconch of *Acroloxus* is not indented (see RIEDEL, 1993) but otherwise is similar to that of ancylid species. The teleoconch of modern species of *Acroloxus* usually does not have the prominent ribbing of ancylid species. *Ferrissia* has a protoconch that is very close to that of the fossil limpets found at Al Qarn Formation (BROWN, 1980: fig. 79f). Thus, the species with a small limpet shell that could represent a member of *Ancylus*, *Acroloxus* or *Ferrissia* from Al Qarn Formation is placed into the later genus due to the shape and ornament of its embryonic shell.

Ferrissia urdunica n. sp.
(Pl. 5/1–8)

Diagnosis: The small limpet with growth lines as ornament has a half-globular embryonic shell with a small central pit from which radial grooves and ridges arise which still on the embryonic shell branch. They end in the margin of the embryonic shell and its transition into a low non coiled cup like shell with long-oval aperture.

Holotype, origin of the name and type locality: The individual on pl. 5/1 represents the holotype. It was collected by us at the type locality of the Al Qarn Formation next to King Abdulla Canal in the northern Jordan Valley. The holotype is housed in the collection of the Geologisch-Paläontologisches Institut und Museum, Hamburg University, no. 4713.

Description: The small limpet has very fine radial ridges on its apex that is taken by the embryonic shell (pl. 5/3, 6, 8). The apex is evenly rounded and has a central narrow rounded pit. The fully grown shell appears to have had only 2 mm in maximal diameter with evenly rounded aperture that is a little narrower in the back than in front. The apex lies slightly towards the left and nearer to the end of the shell than to its front.

The embryonic shell measures approximately 0.4 mm in width and has almost circular outline. Its central part forms a low depression with a narrow central pit (pl. 5/3, 8). From the margins of this pit approximately 25 narrow grooves separated from each other by broader, low and rounded ridges arise and continue over the surface of the cap-like embryonic shell. The distance of the grooves to each other remains similar, so that new ones arise between the ridges and approximately three times as many grooves as in the center reach the margin of the embryonic shell.

The time of hatching from the egg is indicated by strong growth lines and later by a change in ornament and slope inclination. While the embryonic shell is a cup with circular outline the teleoconch is of oval outline with broader front than back. The fully grown shell has the protoconch just behind the middle of the cap-like shell and width of the shell is about half of its length. The protoconch lies on the left side of the limpet with increments of grow denser to each other on the left side than on the right. Ornament of the teleoconch consists only of increments of growth.

Discussion: During development of the embryo, in case of *Ancylus,* yolk is taken from the yolk-rich liquid of the egg in such quantities that the embryo rapidly increases in size and shell calcification is retarded up to the point of growth when a limpet shape has been reached reflecting the shape of the adult shell even before hatching from the egg. A coiled shell is no longer present at all and the torsion of the visceral mass that is also present in the soft body is not reflected in the shape of the shell. In case of *Ferrissia urdunica* the shell of the tiny limpet was calcified when the animal had hatched from its egg case, as is seen on figure 7 in plate 5. Here the margin of the embryonic shell was fractured when the animal had just hatched and the limpet teleoconch was grown attached to it.

The same kind of ontogeny as can be interpreted from the characters of the embryonic shell of *Ferrissia urdunica* is present in several of the limpet like basommatophorans such as *Ancylus*, living *Ferrissia* and *Acroloxus*, which all occur in the Mediterranean regions. They can be distinguished from each other by anatomical features (HUBENDICK, 1970), but apparently also by the ornament of their embryonic shell.

It is assumed that also in case of *Ferrissia urdunica,* that its young hatched from their egg case when their shell consisted of an about 0.4 mm large cap. In case of *Ancylus fluviatilis* the embryonic shell is larger and its transition into the teleoconch less strongly noted in the change of ornament, which represents a good difference to what is seen in *Ferrissia*, where the margin of the embryonic shell is much better set of from the begin of the teleoconch, in shape as well as in ornament. The embryonic shell of *Acroloxus lacustris* is larger (0.5 mm) and it is of a more oval shape. It also has the change in ornament from axial ribs and grooves of the embryonic shell to growht lines on the teleoconch (RIEDEL, 1993), but the axial ribs are fewer, coarser and they do not increase in

number towards the margin of the embryonic shell. As in *Ferrissia* the central portion of the protoconch is flattened with a small groove, and not formed by an irregular depression as is found in *Ancylus fluviatilis*.
These small gastropods live submerged and attached to hard substrates. Their wide open pallial cavity serves in the exchange of gases between water and blood. The ontogeny is characterized by the dealing with much yolk. Yolk is taken from the albuminous liquid of the egg in such quantities that the shell calcification is retarded until the limpet shape of the adult shell has been reached. A coiled shell is no longer present at all and the torsion of the visceral mass is not reflected in the shape of the shell (RIEDEL, 1993; BANDEL & RIEDEL, 1994).
In the Al Qarn deposits the shells of the small limpet are not common. The specimens from Al Qarn Formation are quite characteristic but the genus has not survived in Jordanian waters. From Israel *Ancylus* is usually attached to some object, a stone or another shell and it grazes on algal covers. The genus *Ferrisia* with species *Ferrisia clessiniana* (JIKELI, 1882) according to HOROWITZ (1979) was determined as *Acroloxus lacustris* of Lake Hula and was also found in the Pleistocene deposits in the Ubeidiya but not of the Erk el Ahmar Formations. It may represent the same species as that here described *Ferrissia urdunica* and the latter is here based on 12 individuals which could be encountered from the Al Qarn locality.

Bivalvia

The extant bivalves of Jordan belong to *Unio*, *Corbicula* and *Pisidium*, of which *Pisidium* is not rare in Al Qarn Formation, while *Unio* was found only in the form of brittle fragments in the field and could not be saved and determined to the species. Its characteristic shell shape and the thick nacre layers were recognized, but the nacre had lost its organic components and could thus not be touched without destroying the shell. It probably is the same or a very similar species to the *Unio* which are found as fossils of the Jordan River deposits formed before flooding of Lake Lisan and as are living in King Abdullah Canal. These are *Unio semirugatus* LAMARCK, 1819, and *Unio terminalis* BOURGUIGNAT, 1852, which live in the canal, as well and in Lake Tiberias (TCHERNOV, 1975b).

Genus *Pisidium*
(Pl. 5/9–11)

The *Pisidium* from Al Qarn Formation was not determined to the species. Ontogeny here is connected to a brood pouch from which miniature adults hatch, as was documented by BANDEL (1988: figs. 13–15) and as is seen on the growth increments of the embryonic shell. (BANDEL, 1988) (pl. 5/10).
Pisidium casertanum (POLI, 1795) and *Pisidium annandalei* PRASHAD, 1925, were collected in Jordan in the year 1978 from the spring in Wadi Hisban, and in a mineral spring near the bridge across the Zerqa (now destroyed) and the small lake in the Roman Pool on the highway Amman–Jerash by BANDEL (1978) and was described by SCHÜTT (1983: fig. 16).
HOROWITZ (1979) found *Pisidium* in modern Lake Hula and the fossil lake of Ubeidiya Formation. Several other species of *Pisidium* were described from the middle Pleistocene, and *Pisidium* also occurs in the lake in which Al Qarn Formation was deposited. *Pisidium annandalei* also has the ornament with a fine concentric pattern of ribs, and is distinguished by a characteristic groove of the ligament found in springs in Hisban and Wadi Sir (1978), and described by SCHÜTT (1983: fig. 15). HOROWITZ (1979) determined the same species from Lake Hula together with *Pisidium casertanum*. A *Pisidium* sp. was noted by NELSON (1973) to occur in Azraq Oasis.
Pisidium from Al Qarn Formation is not common, sometimes preserved with both valves still in contact. The shells are very delicate and when sediments are not handled carefully shells are broken.

4 Conclusions

Many gastropods from Al Qarn Formation still have living relatives in Jordanian fresh water creeks and ponds, with the exception of those of the genera *Islamia*, *Bithynia* and *Ferrissia*. In case of *Melanopsis* two species from Al Qarn Formation are so similar to forms now living in Jordan that they cannot be distinguished from them; the other three differ little and only *Melanopsis tchernovi* has no counterpart among the living but a certain resemblance with *Melanopsis sharhabili* form Jordan Valley. *Theodoxus* from Al Qarn Formation has rather peculiar shape and ornament, but among the varieties of *Theodoxus jordani* as they live in the King Abdulla Canal near its connection to the Yarmouk River individuals with very similar shapes are living. The ornament of the shell of *Melanoides* formed during its early ontogeny from Al Qarn Formation indicates that it is not the same species of the genus that is common in Jordan nowadays. *Valvata cristata* and *Valvata saulcyi* may still live in the region around the Jordan Valley but have not been encountered by us as living here now.

Galba and *Gyraulus* from Al Qarn Formation closely resemble those living now. *Galba* occurs as living in clean creeks such as that near springs in Wadi Hisban and *Gyraulus* is rarely encountered in springs and ponds in the carbonate free sandstone area in the southern part of the country near the town Disi and Wadi Rum. In case of *Ferrissia* the embryonic shell needs to be known in order to distinguish it from *Ancylus* as is reported to occur in waters of Israel or from *Acroloxus* that has also been reported from Hula Lake and Lake Tiberias. The bivalves *Unio* as well as *Pisidium* lived in the Al Qarn waters, and may be the same species as occur in case of *Unio* in the canal near the outcrop and in case of *Pisidium* in clean water of ponds and irrigation canals in Jordan

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Plate 1

All fossils from Al-Qarn Formation.

Fig. 1: Valve of an ostracod with 0.7 mm in length.

Fig. 2: Valve of an ostracod with 0.9 mm in length.

Fig. 3: Part of the claw of *Potamon* with 3.5 mm in length.

Fig. 4: Part of the claw of *Potamon* with 4 mm in length.

Fig. 5: *Theodoxus* cf. *jordani* with 2 mm high juvenile shell consisting of the first whorl of the teleoconch. The outer calcitic layer has partly fallen off.

Fig. 6: The operculum of *Theodoxus* cf. *jordani* is calcified and provided with teeth on its hinge, one like a ridge, the other a peg. Length of the operculum is 3.2 mm.

Fig. 7: The embryonic shell of *Theodoxus* cf. *jordani* is the first whorl and is distinct from the teleoconch and measures 0.8 mm.

Fig. 8: The shell of *Theodoxus* cf. *jordani* consists of an outer calcitic layer see in the upper portion with growth lines and the aragonitic inner layer that is composed of the needles of the crossed lamellar structure.

Fig. 9: Fully grown *Melanopsis salamei* with the shell with 2.7 cm in height seen in apertural view.

Fig. 10: *Melanopsis salamei* as in fig. 9 seen from the back.

Fig. 11: Apertural view of *Melanopsis salamei* with the shell 3 cm high and representing the holotype.

Fig. 12: *Bithynia syriaca* with 1.8 mm high shell, rounded whorls and slight spiral ornament.

Fig. 13: Fully grown *Bithynia syriaca* with 2.2 mm high shell.

Fig. 14: *Bithynia syriaca* in fig 12 seen from the back.

Fig. 15: *Bithynia syriaca* with the embryonic whorl that measures 0.35 mm and consists of a little more than one whorl. Its transition into the teleoconch lies next to the strong growth lines.

Fig. 16: The embryonic shell of *Bithynia syriaca* seen from the side and 0.35 mm wide with begin of growth lines.

Fig. 17: Juvenile shell of *Bithynia syriaca* with first whorl of the embryo with 0.35 mm in width, succeeded by the teleoconch shell of the juvenile.

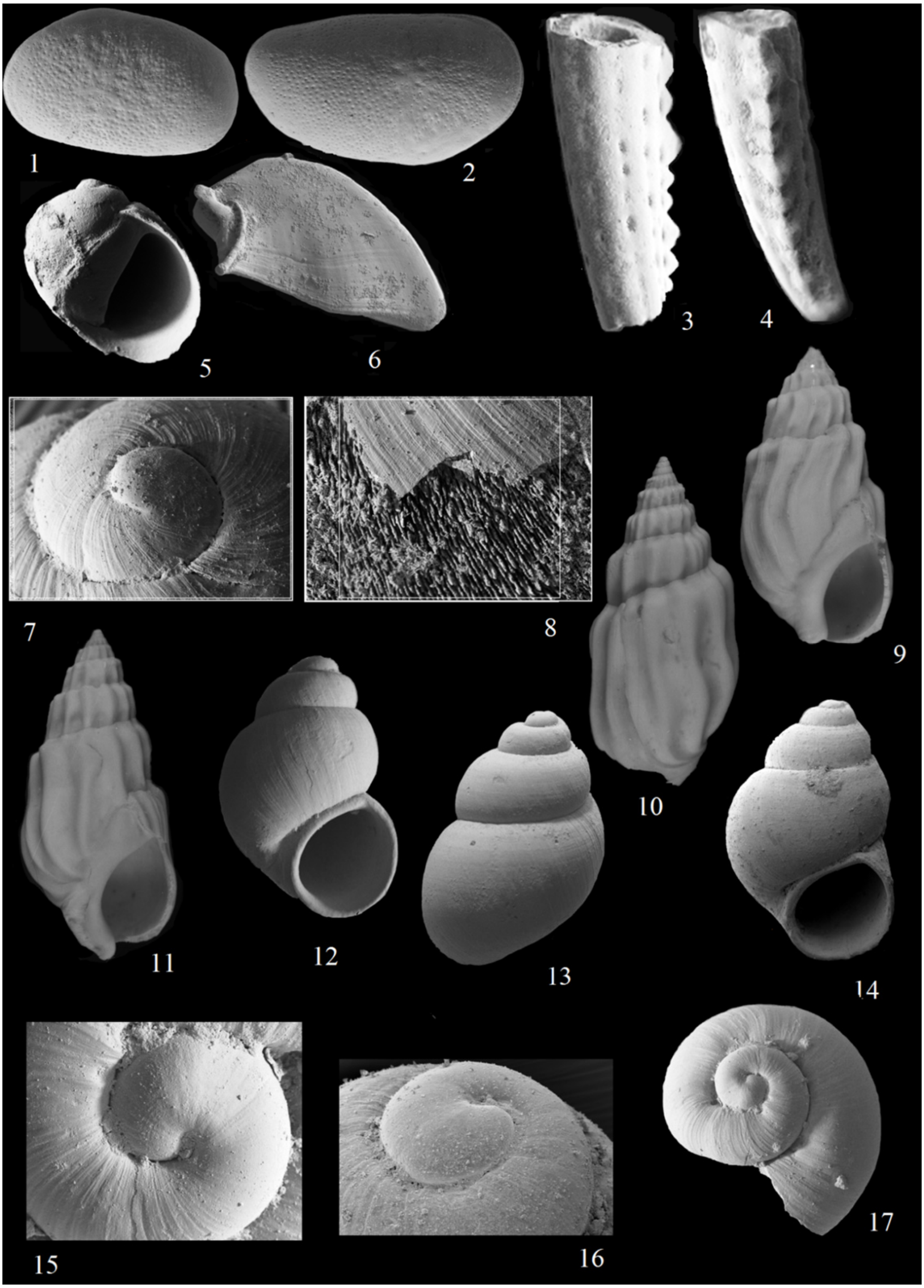
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Plate 2

All fossils – with exception of fig. 15 – from Al Qarn Formation.

Fig. 1: *Hydrobia* cf. *acuta* with its shell with 4.5 whorls is 1.7 mm high and almost 1 mm wide.

Fig. 2: Juvenile shell of *Bithynia syriaca* with thin shell wall.

Fig. 3: Juvenile shell of *Bithynia syriaca*.

Fig. 4: Juvenile *Bithynia syriaca* that resembles the shell of *Islamia* in size but has inclined growth lines.

Fig. 5: Embryonic whorl of *Bithynia syriaca* with indistinct transition of protoconch to teleoconch.

Fig. 6: Apical view of *Islamia jordanica* with the protoconch consisting of the embryonic shell that is distinguished from the teleoconch by strong growth increments and granular ornament.

Fig. 7: Fully grown *I. jordanica,* shell diameter 1 mm (width and height), protoconch 0.25 mm wide.

Fig. 8: Fully grown *Islamia jordanica* that had repaires its shell several times during its life. The illustrated specimen represents the holotype.

Fig. 9: Embryonic shell of *Islamia jordanica* is trochispiral and consists of 1.5 whorls with granular ornament and is 0.3 mm wide.

Fig. 10: Umbilical view of *Islamia jordanica* with the inclined aperture.

Fig. 11: Not full grown *I. jordanica* from the side and without irregularities of growth near the aperture.

Fig. 12: The juvenile shell of *Melanoides abuhabili* is ornamented by two spiral ribs crossed by axial ones. In the first whorl of the teleoconch the axial ribs are close to each other and weak, while on the second they are placed more distant to each other and of the same strength as the spiral ones and in the third whorl the axials are even more distant. The shell is 2 mm high.

Fig. 13: The ornament of the first postembryonic whorl of *Melanoides abuhabili* consists of 30 axial ribs, while approximately 20 are on the second whorl of the teleoconch and the third has about 12 ribs. The figure shows the holotype.

Fig. 14: Juvenile shell of 2 mm in height of *Melanoides abuhabili* that may have been of a specimen that had just left the brood pouch of the mother snail.

Fig. 15: Juvenile shell of *Melanoides tuberculata* from the King Abdulla Canal with ornament of the first whorls succeeding the protoconch is ornamented by more than 40 axial ribs and only later axial ribs become dominant while lateral ones decrease in size. The shell is approximately 1.5 mm high.

Fig. 16: Juvenile shell of *Melanopsis salamei* with the early whorls smooth and ornament inserting with the 4^{th} whorl and the shoulder appearing in the 5^{th} whorl. The shell is 4 mm high.

Fig. 17: Juvenile shell *Melanopsis salamei* with 5 mm shell height and a more rapid appearance of the shoulder as in the individual in fig. 16.

Fig. 18: Juvenile shells of *Melanopsis costata* with shell height of 2.5 mm and the indistinct appearance of axial ornament in the fourth whorl of the teleoconch.

Fig. 19: *Melanopsis salamei* juvenile from Al Qarn Fm. is 5 mm high with the shoulder well expressed in the 6^{th} whorl, while the first whorls are smooth and axial ornament appears in the 5^{th} whorl.

Fig. 20: Juvenile shell of *Melanopsis buccinoidea* that is 2.5 mm high and closely resembles that of *Melanopsis costata* as in fig. 18, but without the appearance of ribs.

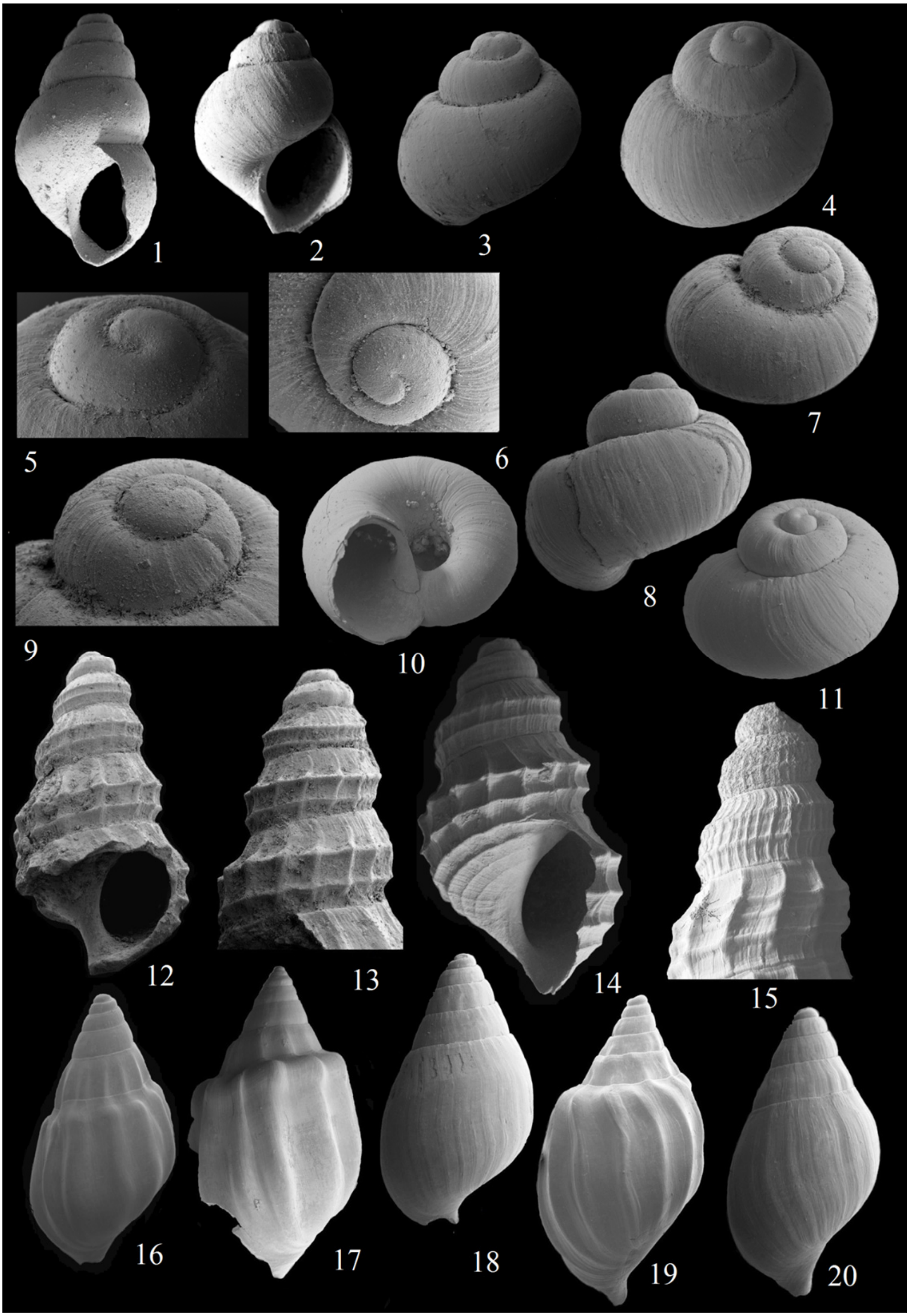
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Plate 3

All fossils from Al Qarn Formation.

Fig. 1: Juvenile shell of *Melanopsis buccinoidea* is 5 mm high.

Fig. 2: Juvenile shell of *Melanopsis tchernovi* with shoulder and smooth sides is 7 mm high.

Fig. 3: Apical view of juvenile *Melanopsis salamei* with the appearance of the ornament only in the fourth whorl, and of the shoulder in the fifth whorl.

Fig. 4: *Valvata cristata* with fully grown shell of 2 mm width and with 3.3 whorls almost in one plane.

Fig. 5: The protoconch of *Valvata cristata* of 0.35 mm in diameter and the initial part dipping below the coiling surface since it is sinistral. An ornament of fine spiral lines covers the embryonic shell and ends in the transition to the teleoconch with onset of growth lines.

Fig. 6: The protoconch of *Valvata cristata* seen from the umbilicus of the teleoconch with 0.35 mm in diameter has its apical end slightly twisted to the left.

Fig. 7: *Valvata cristata* seen from the side with 2 mm wide shell.

Fig. 8: *Valvata cristata* with coiling of the protoconch deviating somewhat from that of the teleoconch.

Fig. 9: *Valvata saulcyi* shell that consists of three to 3.2 whorls with a little more than 2 mm in diameter.

Fig. 10: The protoconch of *Valvata saulcyi* has growth increments on the embryonic shell and a fracture and repaired shell in the freshly hatched individual.

Fig. 11: *Valvata saulcyi* seen in inclined view.

Fig. 12: *Valvata saulcyi* with umbilicus and round aperture.

Fig. 13: Apical view of *Valvata saulcyi* with the protoconch in the first whorl and the rather indistinct transition into the teleoconch.

Fig. 14: The initial part of the embryonic shell of *Valvata saulcyi* has a weak dip into the apex and the transition of the 0.4 mm large protoconch into the teleoconch is marked by growth lines.

Fig. 15: Apical view of *Galba truncatula* with the embryonic whorl of almost 0.5 mm in width and indistinct transition into the teleoconch.

Fig. 16: *Galba truncatula* seen from the side with 2.5 mm high shell.

Fig. 17: The same *Galba truncatula* as in fig. 16 in apertural view.

Fig. 18: Juvenile shell of *Galba truncatula* with 2 whorls and 1.2 mm in height.

Fig. 19: The protoconch of *Galba truncatula* with its evenly rounded and its transition into the teleoconch is marked by lines of growth.

Fig. 20: Juvenile shell of *Galba truncatula* with 1.1 mm in height.

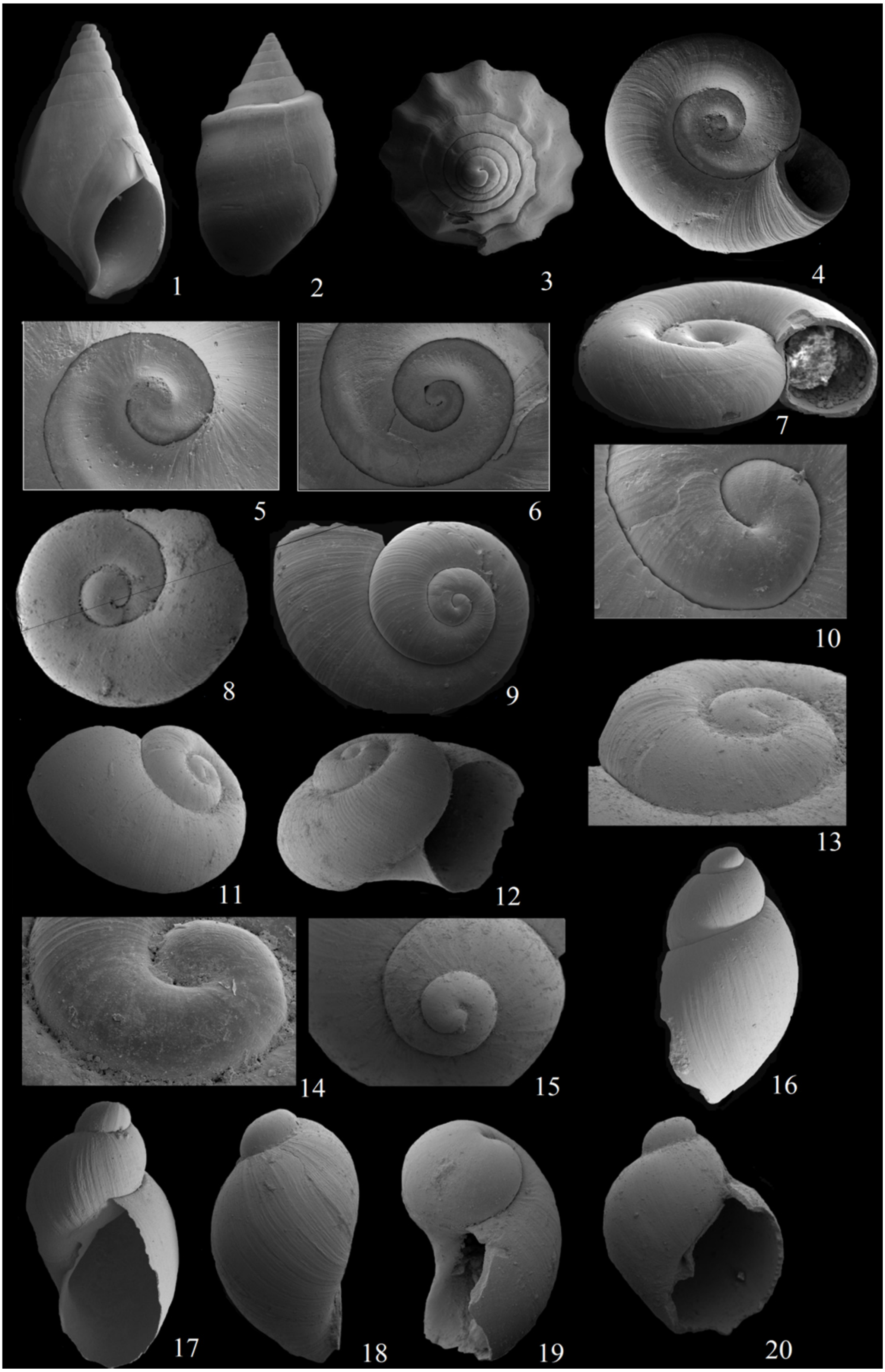
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Plate 4

All fossils from Al Qarn Formation.

Fig. 1: Umbilical view of *Gyraulus* cf. *piscinarium* with 2.5 mm wide shell and three whorls.

Fig. 2: Apical view of *Gyraulus* cf. *piscinarium* with only 2.5 whorls preserved and the protoconch documented in fig. 3; the shell measures 2 mm in width.

Fig. 3: The protoconch of *Gyraulus* cf. *piscinarium* is 0.35 mm wide and has ornament of fine spiral lines which end at the margin of the embryonic shell, while the teleoconch is ornamented by lines of growth.

Fig. 4: Slightly deformed *Gyraulus* cf. *piscinarium* and approximately 1.5 mm high shell with protoconch in fig. 5.

Fig. 5: The protoconch of *Gyraulus* cf. *piscinarium* is approximately 0.35 mm wide and has initial sinistral coiling mode.

Fig. 6: Teleoconch of *Gyraulus* cf. *piscinarium* with almost plane coiling mode and protoconch in fig. 7, and diameter of less than 2 mm.

Fig. 7: The protoconch of *Gyraulus* cf. *piscinarium* in fig. 6 with fine spiral lines succeeded by very fine and regular growth line pattern of the teleoconch.

Fig. 8: Not fully grown shell of *Gyraulus* cf. *piscinarium* with its protoconch in fig. 9 and dense pattern of growth lines.

Fig. 9: Protoconch of *Gyraulus* cf. *piscinarium* with the ornament of fine spiral lines that ends with onset of growth lines.

Fig. 10: Umbilical view of regularly coiled shell of *Gyraulus* cf. *piscinarium* with 1.5 mm in diameter and regular ornament of increments of growth.

Fig. 11: Shell of *Gyraulus* cf. *piscinarium* with 1.3 mm in diameter and strong increments of growth.

Fig. 12: *Gyraulus* cf. *piscinarium* with 1 mm wide shell ornamented by evenly curved growth lines and well distinguished protoconch.

Fig. 13: The shell of *Valvata cristata* resembles that of *Gyraulus*, but is more evenly rounded with the shell 0.3 mm in diameter; protoconch is figured in fig. 14.

Fig. 14: The protoconch of *Valvata cristata* has a more visible sinistral coiling mode as that of the otherwise similar *Gyraulus*.

Fig. 15: The protoconch of this *Valvata cristata* documents that after hatching the juvenile had some problems and only afterwards was able to compose a normal plane shell.

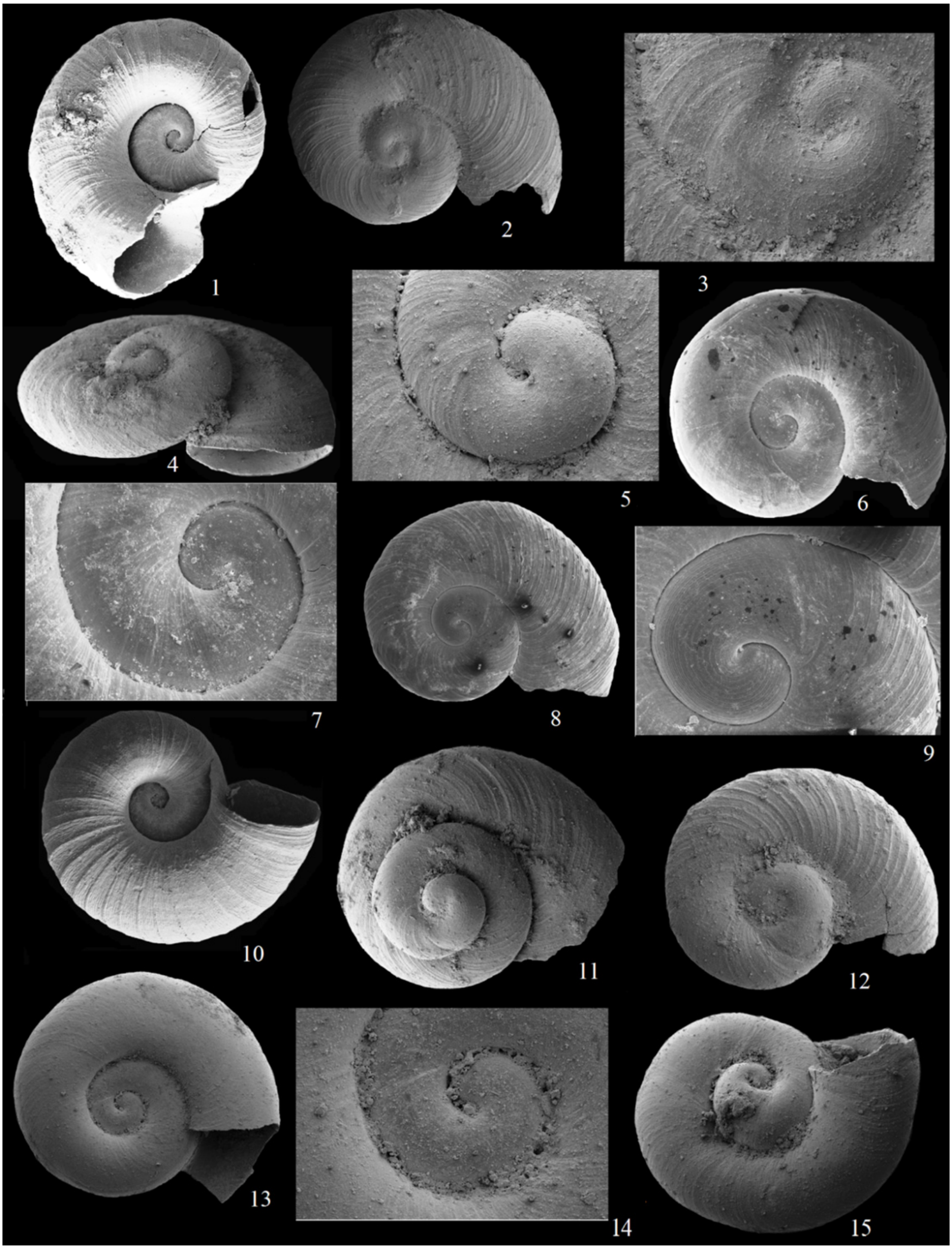
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Plate 5

All fossils from Al Qarn Formation.

Fig. 1: *Ferrissia urdunica* (holotype) with the limpet shell 1.2 mm in diameter and oval rounded aperture that is a little narrower in the back than in front.

Fig. 2: *Ferrissia urdunica* with the shell 2 mm wide in largest diameter and the frontal part of the shell pointing upwards.

Fig. 3: The embryonic shell of *Ferrissia urdunica* seen from the side measures approximately 0.4 mm in width and has almost circular outline and ornament of radial lines.

Fig. 4: *Ferrissia urdunica* seen from the side with the rounded embryonic shell on the posterior side of the limpet that is almost 2 mm in maximum diameter.

Fig. 5: Side view of *Ferrissia urdunica* with the shell measuring 1.4 mm with the rounded cap like protoconch that has strong increments of growth, the posterior art of the limpet-like teleoconch is the shorter one.

Fig. 6: The protoconch of *Ferrissia urdunica* has a central pit and its ornament ends with the onset of the teleoconch which has only lines of growth.

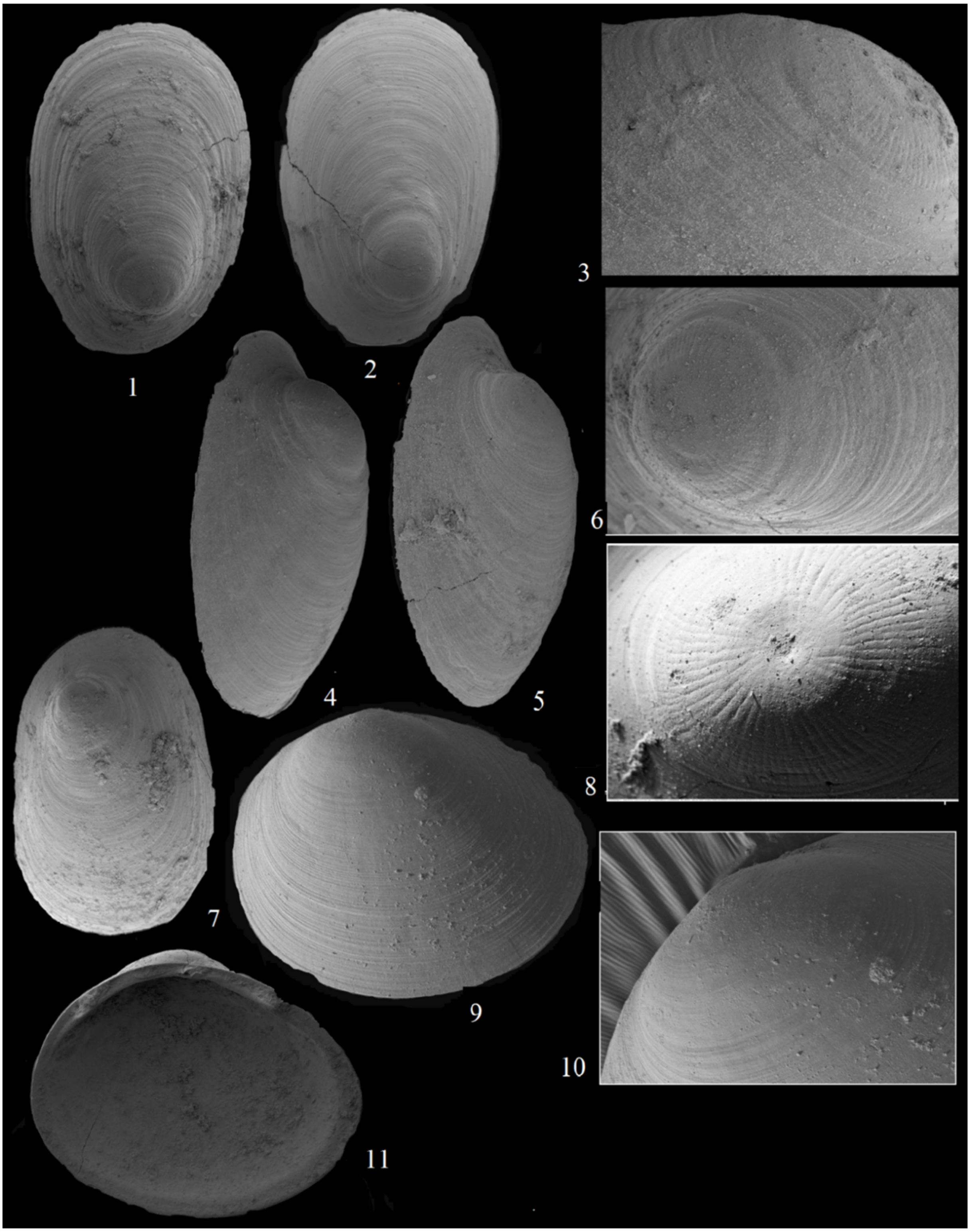
Fig. 7: *Ferrissia urdunica* with the embryonic shell marginally repaired after hatching. The shell measures 1 mm in maximum diameter.

Fig. 8: Protoconch of *Ferrissia urdunica* with an embryonic shell that measures approximately 0.4 mm in width and has almost circular outline.

Fig. 9: Exterior of the valve of *Pisidium* with shell diameter 2 mm.

Fig. 10: Prodissoconcha of *Pisidium* as in fig. 10 documents the absence of a plankton stage during development by having a gradational transition from the embryonic shell to the adult shell.

Fig. 11: Interior of the valve of *Pisidium* with the hinge and a shell diameter of 2.2 mm.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