The Cambrian in Israel and Jordan - the feather edge of the Mediterranean Realm

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The Cambrian of Israel and Jordan belongs to the relatively poorly known regions of Cambrian rocks. The outcrops cover small areas in the southernmost part of Israel, from about 50 km north of Eilat to almost the Red Sea, and areas in the southwestem part of Jordan. The best outcrops are found in the Timna area of Israel, which includes the legendary copper mines of King Solomon, at the eastern shore of the Dead Sea, in the Petra area, and in the Wadi Ram region of Jordan. They belong to a thick blanket of Cambrian through Cretaceous clastics which drapes the northern margin of the Arabo-Nubian Shield and was formerly termed the "Nubian sandstone".

Israel

A number of lithostratigraphic studies have led to a subdivision of the succession in Israel into (from bottom to top) Amudei Shelomo, Timna, and Shehoret formations, with a total thickness of less than 300 m. Except for a more-or-less singular faunal occurrence in the Timna Formation, fossi1s are absent, and reliable age determinations do not exist. However, sedimentological criteria and comparison with neighbormg areas suggest that the deposits result from a comparatively short period of sedimentation around the Lower-Middle Cambrian boundary interval.

The *Amudei Shelomo Formation* consists of fluvial, cross-bedded sandstones. Fossils are unknown from the formation. The *Timna Formation is* currently subdivided into three members, termed the Hakhlil, Sosgun, and Mikhrot members. These members were reported as primarily characterized by sandstones and conglomerates; dolomites, sandstones, and gritty subarkoses; and red and whitish shales, respectively. Fossils were reported to be found in all three members (trilobites from both the Hakhlil and Mikhrot Member, brachiopods from the Sosgun Member).

Recent investigations have shown that the *Hakhlil Member is* a distinct unit of extremely shallow marine to peritidal and subaerial to locally lacustrine deposits with the most unrestricted marine deposits close to the top. these sandstone beds close to the top locally yield body, which consists exclusively, or almost exclusively, of trilobites (including *Myopsolenites palmeri, Timnaella spp.,* and other species). In addition, these beds are locally rich in trace fossils such as *Cruziana, `Monocraterion",* and *Planolites*. The report of *Myopsolenites palmeri* from the *Mikhrot Member* may be erroneous if the layers in question actually belong to the topmost Hakhlil Member, which is directly overlain by the Shehoret Formation at the Har `Arnram locality, and the Mikhrot Member appears to be unfossiliferous.

The *Sosgun Member* consists dominantly of sandstones with a certain dolomite content in the matrix, which is most probably secondary in origin. Distinct major unconformities, which were reported from the member, have not been confirmed in recent studies (Landing and Geyer,

unpublished) so that the reported facies changes may result from differences in dolomitization of the beds.

The *Shehoret Formation* consists of fluvial, cross-bedded sandstones with red and white banded shale units in the lower and upper of the three members. As for the Amudei Shelomo Formation, the lack of fossils and physical age determinations do not permit a reliable age assignment. However, sedimentological characters suggest that deposition of the formation took place in a relatively short period. Only the Timna Formation reaches into depositional environments that allowed the presence of marine invertebrates of late Early to earliest Middle Cambrian age in distinct horizons.

Jordan

The situation in Jordan shows a wide range of depositional environments reflects a generally heterochronous shift of facies belts. Older subdivisions distiguish between a Lower Quweira, a Burj, and an Upper Quweira formation, which could now be shown to be the equivalents to the three formations identified in southern Israel. More recent studies led to a distinction into Saleb, Burj, Umm Ishrin and Disi formations. Modern studies for the Petra area distinguish six formations of Cambrian age, which are (in chronologic order) the Saleb, Nabataeica, Siyagh, Temple, Habis and Ed Deir formations.

Most interesting is the *Buj Formation* that is found only at the escarpment cast of the Dead Sea and south to the Feinan area. In its typical development, this formation is subdivided into three members. The *Tayan Member* consists of laminated, green and red siltstones and fine-grained sandstones of up to 20 m in thickness. It shows laterally accreted channel-fills, wave-ripples, and has a erosive base that indicates a strong truncation of the underlying Saleb Formation. The member includes layers rich in marine trace fossils. The *Numayri Member* consists predominantly of limestone and/or dolomite beds, rhythmically interrupted by thin layers of fine-grained sandstones and siltstones. The total thickness lies between 25 and 60 m. The carbonates include oolites and bioclasts (trilobites, brachiopods, and hyoliths). The upper parts occasionally shows a more restricted facies with stromatolites. Trilobites that are known from the classic Wadi Zarka Ma'in and at the Wadi Hesa sections include *Redlichops blanckenhorni, Ornamentaseis* n. sp., *Kingasp is campbelli, Schistoceehalus cf. antiquus*. Paterinid brachiopods are also frequent in the Numayri Member of the Dead Sea area. The *Hanneh Member* consists of green or reddish siltstones and finegrained sandstones of up to 35 m. The only recognizable biogenic remains are sparse trace fossils. Its base is again at a prominent unconformity, which suggests that it should not be united to a Burj Formation together with the two members below.

Towards the south, the Burj Formation grades into clastic sediments without any body fossils but with clear indications of marine depositional environments. The Nabataeica Formation of the Petra area is its nearshore equivalent and yields an amazingly.complex ichnofossil assemblage (with *CruZiana, Scolicia* and others). In the Wadi Ram area, southernmost Jordan, a ca. 20 cm-thick sandstone at the assumed contact between the Saleb and Umm Ishrin formations yields an ichnofossil assemblage and appears to be the equivalent of the Burj and Nabataeica formations, respectively.

Also in the Wadi Ram area, the Umm Ishrin Formation yields at least one horizon with the trace fossil *Diplichnites,* which was created by marine arthropods. This assemblage indicates that at least parts of the Umm Ishrin Formation was formed under marine conditions and does not consist purely of fluvial deposits (Landing and Geyer, unpublished).

Conclusions

The situation in Jordan matches that seen in Israel. However, the absence of conspicuous, persistent marker horizons makes the subdivision a puzzling story . Recent investigations show that the Burj Formation represents the deposits created by a major, Hawke Bay-type transgression at the Lower-Middle Cambrian turnover, and that the Nabataeica Formation of the Petra area is its nearshore equivalent. In the southernmost part of the modern-day Jordan, the fluvial deposition continued throughout the Cambrian, except for at least two minor interuptions. The Tayan Member suggests a marine incursion over the former alluvial plains and deposition in an intertidal to shallow subtidal environment. The maximum transgression is reflected by the fossiliferous carbonates of the Numayri Member. The northern outcrops of this member demonstrate deposition on a warm, shallow carbonate ramp, with occasional lagoonal influences. The Hanneh Member was deposited in a tidally dominated shoreline environment. Correlation with outcrops in the Petra area poses the question, whether it is the regressive branch of the Numayri peak transgression, or whether it indicates a second, less prominent transgressive event on the Arabo-Nubian Shield: Several aspects appear to favor the second possibility.

The fauna of the Numayri Member permits a relatively precise correlation with lowest Middle Cambrian strata of the western Mediterranean area, and proves the transgression on the Arabo-Nubian Shield to be coeval with the lowest Middle Cambrian transgression known from such areas as southern Morocco and Spain. Body fossils are absent from the Petra area. However, marine trace fossils of the Cruziana assemblage can be found in its middle parta .The feather edge of this transgressive development can be located in the Wadi Ram area, southernmost Jordan, in a ca. 20 cm-thick sandstone with trace fossils at the assumed contact between the Saleb and Umm Ishrin formations.

Outcrops of the Timna Formation in southern Israel show the same pattern in a nearshore to supratidal setting. The Hakhlil Member reflects a transgressive systems tract, with the Sosgun Member being the córresponding high stand systems tract and obviously are the Tayan and Numayri members of the Burj Formation in a more less marine influenced environment. Differences in the biofacies is explained by these different depositional environments.

However, the story of a single marine transgression sandwiched between thick and purely fluvial units is oversimplified. Trace fossils in the Umm Ishrin Formation of the Wadi Ram area testify shallow marine depositional environments well above the Burj Formation and seems to show that the region persisted to vacillate in near-shore depositional environments after the earliest Middle Cambrian.