

## Projection stratigraphy of the upper Eocene Gehannam, Birket Qarun, and Qasr el-Sagha formations and their fossil whales at the Wadi Al Hitan World Heritage Site, western Fayum Province (Egypt)

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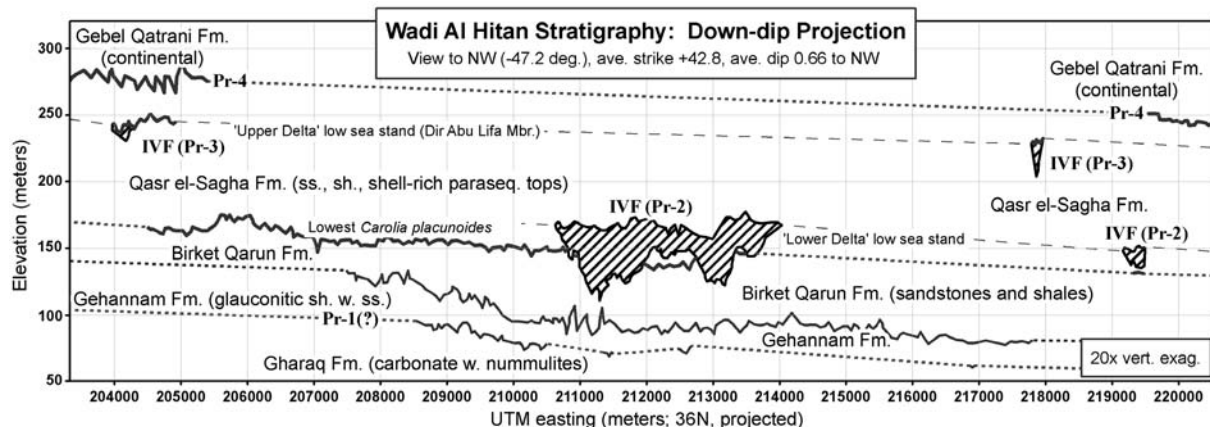
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Wadi Al Hitan or 'Valley of Whales' is a 17 x 17 km UNESCO World Heritage Site in the Western Desert of Egypt. It has a thick sequence of middle and late Eocene shallow marine strata overlain by continental lower Oligocene beds. The marine strata are richly fossiliferous, with more than a thousand skeletons and partial skeletons of fossil whales, sea cows, and other vertebrates mapped to date. Some are exceptionally complete and well preserved. All accumulated in or near the Tethys Sea on a passively subsiding African continental margin. The Gehannam Formation is glauconite-rich with fine-grained carbonate-cemented sandstones at the top. The Birket Qarun and Qasr el-Sagha formations are complexes of fine-grained sandstones, siltstones, and mudstones, with sandy shell beds marking the tops of parasequence in the latter.

The onshore-offshore geometry of Wadi Al Hitan strata is complicated, and lithologies are repeated, making visual correlation unreliable. We are improving the sea level sequence interpretation of Gingerich (1992) by 3D GPS mapping of formation boundaries and key marker beds. Bed traces can then be projected down-dip and/or along-strike to show onlap-offlap geometry. Two macroscale 'deltas' of incised valley fill (IVF) emerge clearly in down-dip projection (Fig. 1). These include numerous transported land-mammal specimens, indicating a fluvial origin. The incised valleys correspond to 3rd-order sequence boundaries Pr-2 and Pr-3 (Peters et al., 2009, 2010; we disavow claims to the contrary by lead authors of Underwood et al., 2011, based on their brief visits to relevant sites). Our study complements Abdel-Fattah et al. (2010) by connecting the lower and upper parts of the sections they studied, but sequence boundary Pr-2 clearly belongs in the lower Qasr el-Sagha Formation in a part of the section not studied by Abdel-Fattah and co-authors.

The lower Gehannam, upper Gehannam through lower Qasr el-Sagha, and upper Qasr el-Sagha formations each have a distinctive archaeocete whale fauna, with *Dorudon atrox* (Uhen, 2004) and *Basilosaurus isis* from the Birket Qarun Formation being the best studied.



**Figure 1.** Projection stratigraphy of Wadi Al-Hitan, here projected down the computed dip. Panel shown is 17 km wide and ca. 250 m high (vertical exaggeration x20). Note that there are two intervals with incised valley fill deposits (IVF; hatched), that represent sequence boundaries Priabonian Pr-2 and Pr-3. The position of Pr-1 is at or near the base of the Gehannam Formation. Pr-4 is on top of the 'Bare Limestone' (carbonate-cemented sandstone) capping the Qasr el-Sagha Formation.