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Examining Exodus 14 with the Geosciences

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Abstract

There are similarities between the physical details described in the Exodus 14 narrative of the parting of the Red Sea, and a wind setdown event in the eastern Nile delta. This publication takes the ocean model results reported by Drews and Han in 2010 and places them in a biblical, archaeological, and historical context. Certain biblical and archaeological research also supports a crossing at the Kedua Gap or possibly at Tell Abu Sefeh. The proposed locations are within 10 km of a place identified as Migdol by several biblical scholars. Four possible crossing sites are evaluated with respect to the biblical text, and what they might imply for the route of a Hebrew exodus from Egypt during the New Kingdom period. The scientific plausibility of the ancient account suggests that Exodus 14 preserves the memory of an actual historical event.

INTRODUCTION

25

26 Exodus 14 describes a dramatic crossing by the Israelites of the Sea of Reeds (Hebrew *yam suf*). Verses
27 21-22 recount the crossing: "Then Moses stretched out his hand over the sea, and the Lord drove the
28 sea back by a strong east wind all night and made the sea dry land, and the waters were divided. And
29 the people of Israel went into the midst of the sea on dry ground, the waters being a wall to them on
30 their right hand and on their left." [ESV] (Crossway 2001) The Jewish historian Josephus gives a slightly
31 different version of Moses' parting gesture: "After this solemn appeal to God, he [Moses] smote the sea
32 with his staff. And at that stroke it recoiled and, retreating into itself, left bare the soil, affording
33 passage and flight for the Hebrews." (Josephus 94) (: 16.2) The Koran adds to this dramatic scene: "We
34 commanded Moses, 'Smite the sea with your staff.' And it parted, and every parting was like a lofty
35 mountain." (Muhammad 653) (: Book 26 The Poets).

36

37 In 2010 Drews and Han reported model results for a wind setdown scenario over the eastern Nile delta
38 in 1250 BC. (Drews and Han 2010) That earlier publication focused on a geographical reconstruction
39 and its hydrodynamic behavior under wind stress. This paper analyzes wind setdown as a possible
40 mechanism to match the biblical narrative of the parting of the sea, examines the biblical and
41 archaeological evidence for a crossing at the eastern end of the ancient Lake of Tanis, and proposes
42 four possible routes for a Hebrew exodus from Egypt. The four crossing sites each hold different
43 implications for the nature of the crossing itself, the duration of the dry passage, and the avoidance of
44 military fortifications along the Ways of Horus coastal road.

45

46 **Wind Setdown**

47 Although the author of Exodus attributes the ultimate cause of the Israelites' deliverance to the Hebrew
48 God, there are enough natural components in the narrative to permit study using the tools of modern
49 science. Is there a scientific basis for the reported events? To a coastal oceanographer, the Exodus
50 crossing has the characteristics of a **wind setdown** event. Wind setdown is a drop in water level caused
51 by strong offshore winds. Wind setdown is the opposite of storm surge and is comparable in vertical
52 displacement, although wind setdown is less well-known because it usually poses no danger to lives
53 and property.(Drews 2009)(Drews and Han 2010)

54

55 The narrative in Exodus 14 has been identified as a wind setdown event since the late 1800s. In 1879
56 Samuel Bartlett suggested a crossing site in the shallows 4 km southeast of Suez (29.954° North,
57 32.569° East), based on local tales of wind and tide.(Bartlett 1879)(: 161, 179-182) Major-General Sir
58 Alexander B. Tulloch personally witnessed a wind setdown event on Lake Manzala in 1882, when a
59 strong east wind blew all night long and dried out the eastern end of the lake.(Tulloch 1896)(Drews
60 2011) Tulloch eventually concluded that the crossing took place between the Great Bitter Lake and
61 Lake Timsah. In 1924 Bo Hellström constructed a wind tunnel and used it to investigate the physical
62 processes behind the parting of the Red Sea. His experimental apparatus employed an underwater sill to
63 model a crossing at Serapeum, between the Great Bitter Lake and Lake Timsah.(Hellström 1950) More
64 recently Nof & Paldor and Voltzinger & Androsov used analytical techniques and a numerical model to
65 analyze wind setdown at an underwater reef 10 km south of Suez (at 29.886° North, 32.546° East).(Nof
66 and Paldor 1992)(Voltzinger and Androsov 2003) Colin Humphreys suggested wind setdown as the
67 mechanism for a crossing at Aqaba.(Humphreys 2003)

METHODS

Exodus 14 contains the narrative core of the crossing of the sea. The interpretive methodology for this study is initially to take the biblical text at face value as a physical description of what happened. If there are details in the narrative that appear not to match the computer simulation, I look for an alternate but still plausible interpretation of the text. Since chapter 14 is narrative prose (unlike the poetry of Exodus 15), one should expect to find only a small number of metaphors and symbolic imagery here.

Other revered literature provides details of the crossing that are not present in the Exodus account. For example, Josephus states that Pharaoh's army had trapped Moses and the Hebrews between the mountains and the sea.(Josephus 94)(: 15.3) There are no mountains mentioned in Exodus 14. In fact, Exod 32:11-12 suggests that the mountains were encountered only **after** the escape from Egypt:

But Moses implored the Lord his God and said, “O Lord, why does your wrath burn hot against your people, whom you have brought out of the land of Egypt with great power and with a mighty hand? Why should the Egyptians say, ‘With evil intent did he **bring them out, to kill them in the mountains** and to consume them from the face of the earth’? Turn from your burning anger and relent from this disaster against your people.[ESV]

Josephus is known to embellish and exaggerate for dramatic purposes.(Maier 1999)(: 14) He changes

89 Moses' gesture (held consistent throughout the plagues) from Moses **stretching out his hand** over the
90 sea (Exod 14:16, 21) into Moses **striking** the water.(Josephus 94)(: 16.2) He adds 250,000 "horsemen"
91 to the pursuing Egyptian force, in an era before the advent of military cavalry. Josephus reports the
92 height of Mt. Tabor as 10x higher than it actually is (30 stades vs. 3 stades).(Maier 1999)(: 14) It falls
93 beyond the scope of this paper to investigate all the discrepancies between the biblical account and the
94 narrative of Josephus. This study is confined to what Josephus himself claims is his **primary source**:
95 the text of the Hebrew Bible.(Josephus 94)(: 16.5) For this reason the present study considers only the
96 narrative core of the sea crossing, which is Exodus 14.

97

98 **Wind Direction**

99 Wind setdown requires a long expanse of water on which to act, and shallow water is more susceptible
100 to wind stress than deep water.(Drews 2009) The best candidates for wind setdown have their primary
101 axis aligned with the direction of the wind. The original Hebrew words for "east wind" in Exod 14:21
102 are "*ruwach qadiym*."(Koehler and Baumgartner 2001) The Hebrew and Aramaic Lexicon of the Old
103 Testament (HALOT) defines "*qadiym*" as "in front, east, eastwards, from the east."(Koehler and
104 Baumgartner 2001)(: 1069) Ezek 11:1 uses "*qadiym*" in reference to the east gate of the Temple. The
105 book of Exodus does not sub-divide the four basic compass points; it records only north, south, east,
106 and west.(Bartlett 1879)(: 179-180) Therefore the allowed wind direction may deviate by as much as
107 45° from each of the four primary directions. A biblical "east wind" blows from some angle within the
108 range of northeast to southeast (total scope of 90°).

109

110 Is a biblical east wind blowing **from** the east, or **toward** the east? Exod 10:19 describes how the plague

135

136 Zech 1:1 states that the book takes place during the reign of Darius I of Persia, and therefore the
137 immediate message of chapter 10 is directed to the Jewish exiles returning from Babylonian captivity.
138 Nevertheless, prophetic images are sometimes repeated in biblical literature (see Isa 7:14 and Matt
139 1:23, Hos 11:1 and Matt 2:15). The promise of deliverance to the Babylonian captives would be
140 strengthened by evoking memories of their ancient deliverance from slavery in Egypt. Thus there is
141 some limited support in Zechariah for a geographical context of the crossing associated with the Nile
142 river.

143

144 It is well known that the Greek Septuagint version of the Old Testament renders "*yam suf*" as "*Erythra*
145 *Thalassa*" in Greek, or "Red Sea" in English.(Kitchen 2003)(: 261-263) What is less well known is that
146 the Septuagint reports the wind direction in Exod 14:21 as a "south wind", blowing from the **south**, not
147 from the east as in the Hebrew Masoretic text.(Athanasius 2008) It is beyond the scope of this paper to
148 analyze compass directions in the different translations of the Pentateuch. Nevertheless, I note that
149 when combined with its rendering of "*yam suf*" as "Red Sea", the Septuagint produces a physical
150 impossibility: A strong wind blowing from the south over the modern Red Sea will **not** produce the
151 wind setdown effect at either Suez or Aqaba. Instead, the water level at the northern extremities of the
152 Red Sea will **rise** (producing storm surge) in response to wind stress from the south.

153

154 **Reconstructing the Lake of Tanis**

155 The eastern Nile delta is subject to a mix of geological processes that is different from those of other
156 sections of the eastern Mediterranean coast. Geologist Jean-Daniel Stanley has shown that although the
157 eastern delta has subsided, recent tectonic uplift along the Pelusium Line fault has preserved this

158 sandstone ridge above worldwide sea level rise, along with the New Kingdom (c. 1550 BC - 1070 BC)
159 sites on top of it and to the south.(Stanley et al. 2008) Huge plumes of sediment from the Nile mouths,
160 swept toward the east by alongshore currents and waves, have also expanded the coastline seaward.
161 Thus the Roman ruins and harbor at Pelusium are not submerged beneath the Mediterranean Sea, but
162 are above sea level and farther from the shore than when they were constructed. Stanley's geological
163 research allows us to reconstruct the geography of the eastern delta with assurance that these sites were
164 coastal and habitable during the Exodus time period.

165

166 What did the eastern Nile delta look like during the Exodus period (nominally 1250 BC,(Hoffmeier
167 1996)(: 126) with some earlier proposals)? Scientific sources do not agree on the exact geography of
168 the eastern frontier during Egypt's New Kingdom, so any reconstruction must proceed with some
169 uncertainty. Ptolemy's *Geography* (AD 150) states that the Nile river had seven mouths opening onto
170 the Mediterranean Sea.(Ptolemy 150)(: 423) Isa 11:15 makes the same statement:

171

172 And the Lord will utterly destroy the tongue of the Sea of Egypt,
173 and will wave his hand over the River with his scorching breath [wind],
174 and strike it into **seven channels**, and he will lead people across in sandals. [ESV]

175

176 In 1800, oceanographer James Rennell created a map of the ancient delta during the Greek classical
177 period based on the writings of Herodotus.(Rennell 1830) The Rennell map is a useful schematic
178 (Figure 2). It shows the Pelusiac branch of the Nile flowing eastward from Cairo, and emptying into the
179 Mediterranean at Pelusium. Of particular interest is Rennell's depiction of the Lake of Tanis, a large
180 coastal lagoon separated from the open sea by a line of coastal barrier islands.

181

182 The Lake of Tanis (ancestral Lake Manzala) is not shown on most archaeological maps, but its
183 presence is supported by evidence from geology,(Stanley and Warne 1993)(Stanley et al. 1996)
184 oceanography,(Drews and Han 2010) and papyrus Chester Beatty II.(Drews 2009)(: 28-29) This
185 protected, shallow lagoon would have been susceptible to strong winds blowing from the east. Over a
186 period of several hours these winds would produce large areas of exposed lake bed on Egypt's eastern
187 frontier. This is a possible location where Moses and the Hebrews were trying to pass through. Table 1
188 shows important New Kingdom sites in the vicinity.

189

190 **ROMS Ocean Model**

191 NASA's Shuttle Radar Topography Mission (SRTM) provides worldwide terrain data at a grid
192 resolution of 3 arc-seconds (86 meters at 30° North latitude). Drews and Han modified this terrain to
193 re-create a likely geography of the Exodus, based on archaeological and geological sources.(Drews and
194 Han 2010) The result is similar to the map of James Hoffmeier and Stephen Moshier,(Hoffmeier 2005)
195 (: his Figure 5) with Rennell and Stanley's coastal sandbar added to create the Lake of Tanis. Figure 3
196 shows the reconstructed geography. To the west of the archaeological site Tell Kedua there is a break in
197 the Pelusium Line, forming a low spot in the sandstone ridge that Drews and Han called the "Kedua
198 Gap." This gap appears on a geological survey of the North Sinai.(Sneh et al. 1975) The lagoons are 2
199 meters deep; this is deep enough to permit navigation by sea-going ships as described by Herodotus,
200 (Herodotus 440 BC) and is close to the present average depth of Lake Manzala (1.3 m).

201

202 The Regional Ocean Modeling System (ROMS) is a computer model that simulates the effect of wind
203 on this domain. The wind velocity is 28 meters per second, comparable to a medium-strength tropical
204 storm on the Saffir-Simpson hurricane scale. This digital wind is programmed to blow for 12 hours -

205 "all that night" according to Exod 14:21 - and then stop. The model continues to run for another 12
206 hours.(Drews and Han 2010)

207

208 RESULTS

209 Four Crossing Sites

210 Simulation experiments performed with ROMS and the Tanis model reveal not just one, but **four**
211 possible crossing sites. Figure 4 shows the maximum extent of wind setdown at 12:00 hours, just
212 before the wind ceases. From north to south there are potential crossings at Tell Kedula, Gilbana, Tell
213 Ahmer, and Abu Sefeh (see Table 2). Each location is an area of exposed lagoon bottom where a
214 number of people could cross the mud flats from west to east and escape from Egypt into the Sinai.

215

216 The crossing at Kedula is the most spectacular, reaching from the eastern end of the Sethrum peninsula
217 across to the bluff at Tell Kedula about 3 km away. Exodus 14, verses 22 and 29, specify a curious
218 hydrodynamic detail: **water was present on both sides of the crossing**. As shown in Figure 4, a group
219 of people standing at the eastern end of Sethrum and facing east would see water on their left side
220 (north), on their right side (south), while a dry passage would be open ahead of them (to the east). This
221 division of waters occurs because the confluence of the Pelusiac branch and the Lake of Tanis forms an
222 angled curve in the combined body of water, and the Sethrum peninsula splits this body as the water
223 shifts to the west under wind stress.(Drews and Han 2010) The water to the north of the Kedula Gap is a
224 high-velocity stream 20 cm deep that issues from the Pelusiac mouth of the Nile at Pelusium. The strait
225 at the Kedula Gap becomes completely dry at 9:24 hours and refills at 13:24 hours, for an elapsed
226 crossing time of 4.0 hours (experiment T14). The dry passage is 4 km wide at 12:00 hours. A follow-up

227 study calculated a dry crossing time of about 8 hours.(Drews 2013)

228

229 Note that Drews and Han (2010) constructed an **idealized** topography for their ocean model. In
230 practice, the Tanis lagoon would have center channels deeper than 2 m. The high-velocity stream north
231 of the Kedia Gap would be deeper than 20 cm, and would generate large waves in windy conditions.

232

233 The site at Gilbana also exhibits water on both sides of a dry crossing. From the tip of the small
234 peninsula northeast of Tell el-Borg, a group of refugees could cross the exposed mud flats and reach
235 permanent land about 1.5 km to the east near the Arab village of Gilbana. The ROMS model shows a
236 pocket of water remaining at the southern tip of the eastern paleolagoon (Figure 4). The Gilbana
237 passage opens at 8:18 hours and closes at 12:48 hours, leaving 4.5 hours for the crossing.

238

239 Tell Ahmer is on the western edge of a marsh extending from the northeast Ballah Lakes to Tell
240 el-Borg.(Moshier and El-Kalani 2008) The shallow waters of the marsh blow away more quickly than
241 the deeper lagoons, revealing a dry crossing at 7:06 hours. The lake water re-floods the marsh at 13:06
242 hours, leaving 6 hours for the passage. Drews and Han made the Ballah marsh 0.5 meters deep, **not**
243 deep enough to drown an adult male. Furthermore, the Ahmer crossing site retains water only on the
244 right (southern) side, and in this respect does not match the narrative in Exodus 14.

245

246 Tell Abu Sefeh is another waypoint along the isthmus of Qantara, between Avaris and the eastern
247 frontier. Here a small peninsula extends into the northeast arm of the Ballah Lakes. Because the
248 primary axis of the Ballah Lakes is not strictly east-west, a dry crossing at Abu Sefeh requires a wind
249 blowing from 40° north of due east (experiment T6). This wind direction is acceptably east by the
250 Hebrew narrative compass. The Ballah Lakes are just barely long enough in this direction (25 km) to

251 generate a wind setdown of 2 meters. The crossing at Abu Sefeh retains water only on the right
252 (southern) side, although there may be small pockets of water remaining north of Abu Sefeh that the
253 ROMS grid cannot resolve. This passage opens at 9:18 hours and closes at 12:06, for an elapsed
254 crossing time of 2.8 hours.

255

256 **Walls of Water**

257 Many depictions of the Red Sea crossing in popular culture portray an event with standing vertical
258 walls of water on either side of the crossing party. The study of fluid mechanics tells us that after the
259 wind ceased, the return wave would behave like a tidal bore,(Kundu and Cohen 2004)(: 233-235) and
260 would appear as an advancing wall of water to any soldiers trapped in the crossing. However, the
261 scenario presented here does not provide for **stationary** vertical walls of water during the crossing.

262

263 The English word "wall" in Exod 14:22 is Hebrew "*chowmah*". HALOT defines "*chowmah*" as "1. city
264 wall; 2. wall around building or area of city; 3. metaphor: wall of water."(Koehler and Baumgartner
265 2001)(: 298) They give Exod 14:22-29 and 1 Sam 25:16 as examples of metaphorical usage. Brown,
266 Driver, and Briggs (BDB) note that "*chowmah*" carries the idea of **protection**.(Brown, Driver, and
267 Briggs 1906) "*Chowmah*" in Exodus 14 is the metaphorical description of a **protective barrier** for
268 Moses and the Israelites; the waters on either side of the passage guarded against flank attack by the
269 pursuing chariot army.(Bartlett 1879)(: 182) This interpretation is in accord with similar usage in Nah
270 3:8 "Are you better than Thebes [No-amon] that sat by the Nile, with water around her, her rampart a
271 sea, and water her wall?" [ESV]. Although the same Hebrew word is used in both passages, no biblical
272 scholar claims that the Nile river stood up in a vertical wall as it flowed past Thebes. Instead, the Nile
273 and its canals formed a protective **moat** around the city.

274

275 **Dry Ground and Chariot Wheels**

276 The Hebrew word "*charabah*" used in Exod 14:21 is translated as "the dry land" in English.(Koehler
277 and Baumgartner 2001)(: 350) "*Charabah*" refers elsewhere in the Old Testament to land emerged from
278 or contrasted with the sea (Gen 7:22, Jos 3:17, Jos 4:18). Exodus 14 states in verses 22 and 29 that the
279 Israelites walked through the middle of the sea on "dry ground". "Dry ground" in these two verses is
280 Hebrew "*yabbashah*." "*Yabbashah*" in the Old Testament also carries the meaning of land recently
281 emerged from the sea, or land contrasted with the sea.(Koehler and Baumgartner 2001)(: 384) There is
282 no biblical requirement here in the text for zero soil moisture, nor any indication that the ground was
283 "parched" or "desiccated". The text of Exod 14:21, 22, and 29 is satisfied if the seawater drains from
284 the terrain but still leaves the surface wet to the touch; the exposed lagoon bottom is still considered to
285 be "*charabah*" and "*yabbashah*".

286

287 Yet Exodus 14 verse 25 states that the wheels of Pharaoh's chariot wheels were "clogged" so that they
288 "drove heavily".[ESV] The Samaritan Pentateuch and the Septuagint report in verse 25 that the chariot
289 wheels fell off. Taken together, these verses pose a physical problem: How could the bottom of a
290 muddy lagoon be made firm enough to walk upon, yet prevent wheeled vehicles from traveling across
291 the same surface? The Tulloch account mentions that "the natives were walking about on the mud" of
292 the exposed bottom of Lake Manzalah,(Tulloch 1896) and from this report we may presume that the
293 mud flats at his location were at least passable on foot. However, the model results from Drews and
294 Han (2010) can provide a more quantitative answer to this question.

295

296 The Kedia Gap represents a strait between the eastern paleolagoon and the Lake of Tanis to the north.
297 This strait restricts the water flow and increases the current speed. Tanis experiment T4 models the
298 Kedia Gap at its lowest water level, beginning with the lagoon in a quiescent state, with no influence
299 from winds or tide throughout the model run. The only flow source in T4 comes from the Pelusiac
300 branch during the spring season.(Drews and Han 2010) Experiment T4 shows the current in the strait
301 stabilizing at about **2 cm/sec**. This value represents the lowest current flow in the area of the crossing
302 that we would ever expect without even minimal wind or tidal forcing.

303

304 Figure 9B of Drews and Han (2010) shows sustained currents in the Kedia Gap on the order of **30**
305 **cm/sec**. Since the Tanis experiments represent an extreme meteorological case, this value represents the
306 greatest current flow in the Kedia Gap that one could ever expect to observe over perhaps decades of
307 yearly Nile cycles. Thus the extreme range of currents within the Kedia Gap is: **2 - 30 cm/sec**. These
308 current values are largely consistent along the whole route of the proposed crossing, with an increase
309 up to about 70 cm/sec at the far western end of the strait.

310

311 Let us consider a more normal range of current flow by selecting from the extreme range a central
312 subset. Since the relationship between water flow and sediment size is logarithmic, the central third of
313 the range 2 - 30 cm/sec is calculated from the log of the current to be: **5 - 12 cm/sec**. This subset should
314 represent the range of current flow during a normal year of the Nile river. The Hjulström curve between
315 transport and deposition shows that the grain size for this range of currents is **0.9 mm - 2.5 mm**.
316 (Hjulström 1939) Filip Hjulström defines "coarse sand" as having a diameter of 1 mm or greater.(p. 21)
317 Thus Moses and the Israelites would be walking not through silty mud, but across **coarse sand**. The
318 author has found informally that the coarse sand of a volleyball court is easy to walk across but difficult

319 to traverse on a commuter bicycle. Note that for the extreme current range the Hjulström curve gives
320 values for the grain size of 0.3 - 12 mm (medium sand - pebbles).

321

322 Although the narrative in Exodus 14 does not use Hebrew words that might indicate the level of soil
323 moisture within the crossing, there is some reason to expect that the sandy surface might indeed be dry
324 to the touch. Exod 14:21 states that a strong east wind blew all night long and drove back the sea, and
325 the waters were divided. The character of an Egyptian east wind is given in Genesis 41 during
326 Pharaoh's dream. The Hebrew word used is "*shadaph*," which carries the meaning of scorching,
327 blighting, and withering. The east wind "blighted" the ears of grain (verses 41:6, 23, and 27 [ESV]) and
328 caused a famine. Wet surfaces will dry faster if they are exposed to a strong wind. The author has
329 observed this effect informally with a leaf blower and a wet cement driveway (Figure 5). One would
330 reasonably expect the dry sandy surface of the Kediah Gap to become churned up by the passage of the
331 Israelites and their cattle, leaving a more difficult surface behind them for the pursuing chariot force to
332 traverse.

333

334 **DISCUSSION**

335 Exod 14:1-2 records very specific directions: "Then the Lord said to Moses, 'Tell the people of Israel to
336 turn back and encamp in front of Pi-hahiroth, between Migdol and the sea, in front of Baal-zephon; you
337 shall encamp facing it, by the sea.'" [ESV] "Between Migdol and the sea" is a key phrase for locating
338 the famous crossing. James Hoffmeier has provisionally identified the archaeological site T-78, at the
339 southern end of the eastern paleolagoon, as Migdol of the Exodus narrative.(Hoffmeier 2005)(: 105)
340 The nearby site Tell el-Borg is another possibility, or perhaps the entire area of the two sites could be

341 viewed in the context of Exod 14:2 as "the Migdol cluster". If this identification is correct, then all four
342 of the crossing sites revealed by the ROMS ocean model are in some way located "between Migdol and
343 the sea". They are all within 10 km of Migdol, and they all have some large body of reedy water in the
344 opposite direction. Thus ocean modeling represents an independent line of evidence supporting
345 Hoffmeier's identification of Migdol with either T-78 or Tell el-Borg. Table 2 shows the four crossings
346 and the implied bodies of water through which Moses would pass.

347

348 **Exodus Route**

349 The discovery of four potential crossing sites near a place called Migdol encourages some informed
350 conjecture regarding the route of the Exodus. The sites' location at the northern end of the isthmus of
351 Suez supports the "traditional route" of the Exodus, at least until entering the Sinai Wilderness. The
352 traditional route enters the Wadi Tumilat from the north, turns back north at Ismailia (Etham), then
353 passes to the east near Qantara before heading south again.(Zodhiates 1991)(: map The Exodus)(Beitzel
354 2006)(: 155)

355

356 The ROMS model supports the interpretation by Propp, Kitchen, HALOT, and BDB that the Hebrew
357 word "*shuwb*" for "turn back" in Exod 14:2 means not merely a course correction, but a **reversal** and a
358 **return back** toward the original position.(Propp 1999)(: 490)(Kitchen 2003)(: 259-260)(Koehler and
359 Baumgartner 2001)(: 1427)(Brown, Driver, and Briggs 1906) "*Shuwb*" is used in Exod 14:26, 27, and
360 28 to describe the water **flowing back** to its natural seabed by gravity after the wind had stopped, as the
361 hydraulic model shows. Turning northward at Etham would set Moses **back** on a course toward his
362 starting location at Ramses. Although a move back north from Etham seems illogical for a party
363 intending to avoid the Mediterranean coastal route, the biblical text indicates that this was indeed the

364 case.(Hoffmeier 2005)(: 71-72)

365

366 A crossing at Kedia would require Moses and the Hebrews to cross the Pelusiac branch of the Nile
367 from south to north at the site later called Daphnae, then proceed to the eastern end of the Sethrum
368 peninsula along the marshy southern shore of the Lake of Tanis. This route has the advantage of
369 bypassing the Migdol fortified zone (Hebua, el-Borg, T-78) to the west and north. The eastern tip of
370 Sethrum would likely be **unguarded**, as the ancient Egyptians would consider 3 kilometers of water to
371 be an impenetrable barrier to walking refugees. There is room here for an armed standoff between two
372 large groups of people. After the crossing, any route across the Sinai would be open to Moses and his
373 company (Figure 6).

374

375 The approach to the Gilbana crossing plunges straight into the heart of the Migdol cluster of military
376 sites. It may have been possible to take a road along the Qantara isthmus on the south bank of the
377 Pelusiac, instead of taking the sandstone ridge on the north bank, thereby bypassing Hebua I and II.
378 Nevertheless, the fortress at Tell el-Borg would be squarely in Moses' path, and T-78 would present an
379 additional barrier to overcome. These military obstacles pose difficulties for the Gilbana hypothesis
380 that must be addressed.

381

382 The crossings at Ahmer and Abu Sefeh would require any company of Hebrew refugees to approach
383 the Migdol fortified zone from the southwest, but not enter it. In both cases the final encampments
384 would be at small promontories on the eastern side of the Qantara road, facing across the northeastern
385 lobe of the Ballah Lakes. These sites have a significant drawback in that they do not exhibit water on
386 both sides of a dry passage, and so do not match the biblical narrative.

387

388 Exod 13:17 states that the Hebrews did not take the "way of the land of the Philistines", because this
389 northern coastal route was fortified. Hoffmeier (2005: 65-6) equates this route with the "Ways of
390 Horus", meaning that the forbidden road began at Tjaru (Hebua I) and ended at Gaza. I suggest that
391 since the Waters of Horus are confined to the eastern Nile delta, and the Philistine terminology reflects
392 the later perspective from Canaan; then the "Ways of Horus" signified the military road **west** of the site
393 later known as Pelusium (27 km), while the "way of the land of the Philistines" referred to the longer
394 section from Pelusium to Gaza (170 km). Since none of the four crossings require travel eastward
395 beyond Pelusium, Exod 13:17 would be satisfied if the verse refers only to the road beyond the eastern
396 Nile delta.

397

398 Clearly the intent of Exod 13:17 is to avoid military fortifications, and the Ways of Horus was
399 well-fortified. Consider first the approaches to Gilbana, Ahmer, and Abu Sefeh: only the Gilbana
400 crossing actually travels upon the Ways of Horus for a distance of about 6 kilometers. Since the
401 Hebrews were approaching the Migdol cluster from the south, they would logically traverse the shorter
402 isthmus of Qantara rather than confront Hebua I and II. Their closest approach at Ahmer would bring
403 them to 5 kilometers from Hebua II but no closer.

404

405 Now consider the western approach to the Kedia Gap. Figure 6 shows the Kedia route; it passes about
406 4 km north of Hebua I along the marshy southern shore of the Lake of Tanis, then **crosses** the Ways of
407 Horus after the *yam suf* passage. Therefore the Kedia, Ahmer, and Abu Sefeh crossings carefully
408 **bypass** Pharaoh's forts and garrisons. Exod 13:17 is a valid objection only to the Gilbana crossing.

409

410 **Pi-hahiroth and Baal-Zephon**

411 Hoffmeier's identification of Migdol leaves the sites of Pi-hahiroth and Baal-Zephon to be located.

412 Pi-hahiroth is thought to mean "mouth of the canal(s)." (Kitchen 2003)(: 260)(Hoffmeier 2005)(: 105)

413 During the New Kingdom period, the Pelusiac branch of the Nile served as a canal for transportation

414 and irrigation, bringing water to the eastern delta region. The Pelusiac emptied into the Lake of Tanis

415 through the Kedia Gap. Stephen Moshier and Ali El-Kalani have also identified a canal passing

416 through Tell el-Borg and emptying into the eastern paleolagoon. (Moshier and El-Kalani 2008) Thus

417 there are at least two canal mouths at Kedia that would satisfy the meaning of "Pi-hahiroth". During

418 the Exodus period Pi-hahiroth was possibly just a place name, or a small fishing settlement, at the

419 eastern end of the Sethrum peninsula. The archaeological site Tell el-Ghaba here is dated to the early

420 Saite period, 26th dynasty (600 BC). (Goyon 2007)(: 151)

421

422 I have placed Baal-Zephon at the site later known as Pelusium, based on its location on the Rennell

423 map. At the time of the Exodus this cape was rising above sea level due to uplift by tectonic forces.

424 (Stanley et al. 2008) I understand the phrase "facing Baal-Zephon" to mean "looking out across the

425 water toward Baal-Zephon in the distance." Pelusium is a prominent landmark in just the right place; it

426 would be visible from the tip of the Sethrum peninsula, pulling the Hebrews' gaze eastward toward

427 freedom. Perhaps there was a Canaanite shrine to Baal there. Yet the Exodus text never describes

428 Moses actually **reaching** Baal-Zephon. The Rennell map shows ample room for the refugees to cross

429 southeast from the tip of Sethrum, celebrate their deliverance (Exodus 15), and then flee southward into

430 the Sinai wilderness, all without quite passing through Pelusium.

431

432 The geological research by Moshier and El-Kalani (2008) greatly clarifies the topography at the

433 Pelusiac mouth of the Nile. Although Tell Kedu and Tell el-Herr are also across the water from
434 Pi-hahiroth, they were not occupied until after the Exodus,(Hoffmeier 2005)(: 95-96) and so are
435 unlikely to be cited in the triangulation of Exod 14:1-2. The New Kingdom site of Tell Ebedah is
436 another possibility for Baal-Zephon, again based on its location across the water to the east.

437

438 **Ta-denit: The Dividing Waters**

439 The temple complex of Karnak in Thebes, Egypt contains in the Hypostyle Hall a relief attributed to
440 the Pharaoh Seti I (1290–1279 BC). The relief depicts a map of the northeastern border of Egypt, with
441 the Pharaoh returning from a military campaign against the Asiatic *Shasu*, and herding the captured
442 prisoners along a road near a system of waterways.(Hoffmeier 2005)(: 99-101 and Figure 2) Hoffmeier
443 identified this map with the sequence of New Kingdom forts from Hebua to Tell el-Borg and the
444 archaeological site T-78. The waterway is labeled "*t3 dnit*" (pronounced "*ta-denit*") and it is filled with
445 crocodiles; Gardiner translated this Egyptian phrase as the "dividing waters".

446

447 Gardiner explained his translation of "*Ta-denit*" as follows: "The name of the canal (A) was
448 [hieroglyphics] '*Ta-dēnit*,' clearly meaning '*the dividing waters*⁵' and so-called because they sundered
449 Egypt from the desert."(Gardiner 1920) In other words, *Ta-denit* refers to the **boundary waters** that
450 separated Egypt proper from the northeastern frontier along the road to Canaan.

451

452 I propose that the English phrase "the dividing waters" is correct, but may not carry the meaning that
453 Gardiner intended. Instead, *Ta-denit* refers to the dividing waters because **these waters themselves**
454 **divide** when strong winds blow from the east. The Egyptian phrase *Ta-denit* would then preserve the

455 local memory of an unusual phenomenon that occurred at the eastern paleolagoon perhaps once every
456 generation. The geographical toponym "the dividing waters" was given in antiquity to the lagoon and
457 the Pelusiac Nile at Hebua to signify their remarkable behavior whenever a gale swept in from the
458 Arabian desert. The waters separated around the peninsula at Pi-Hahiroth, east of Hebua and north of
459 Migdol. Moses may have been aware of these tales; in any case, the meteorological phenomenon would
460 have been rare enough that neither he nor the pursuing chariot force could know for certain what was
461 going to occur.

462

463 **Exodus 15 - The Song of the Sea**

464 Although this paper is primarily concerned with the single chapter of Exodus 14, the Song of the Sea in
465 Exodus 15 looms large in biblical criticism. Cross and Freedman have concluded:

466 It would appear, therefore, the Song of Miriam [Song of the Sea] is the oldest of the extant
467 sources for this event in Israelite history, being earlier than the parallel prose narratives just as
468 the Song of Deborah is clearly anterior to the prose account in Judges 4. The priority of the
469 poetic form of the tradition over the prose form is normally to be expected in this cultural
470 milieu.(Cross and Freedman 1975)(: 33)

471

472 Kenneth Kitchen disagrees with this general principle:

473 This [example involving the Exodus plagues] illustrates a basic literary phenomenon endemic to
474 the ancient Near East, yet one constantly abused by biblicists. When prose and poetry accounts
475 coexist, *it is prose that is the primary source and poetry that is the secondary celebration*. This

476 cannot be overstressed. (*italics original*)

477 In precisely the same way, Exod. 1-14 is the basic source for the exodus, not either Exod. 15 or
478 Pss. 78, 105; and for Deborah, Judg. 4, not Judg. 5 (for all its considerable value).(Kitchen
479 2003)(: 252)

480

481 Cross and Freedman base their early date (Judges period, 12th century BC) on the historical grammar,
482 lexicography, orthographic data, linguistic characteristics, and metrical structure of the Hebrew poem.
483 Yet it would be difficult for an Iron Age bard from the hill country of Judea to construct a realistic
484 narrative of wind setdown, including the wind direction and duration of the event, based solely on epic
485 poetry. I propose a resolution to this problem by distinguishing between the **language** of the biblical
486 text and the **content** of the text. Both Exodus 14 and 15 are near-eyewitness accounts of a momentous
487 escape by the Israelites through a temporarily dry land bridge in the eastern Nile delta. Both accounts
488 were recorded in some kind of stable form within a generation or two of the actual event. The language
489 of the narrative in Exodus 14 was updated and "modernized" through the ensuing centuries. The
490 meteorological details remained the same out of respect for their history. But the Song of the Sea in
491 Exodus 15 quickly became a beloved hymn of praise to God, and its archaic language was carefully
492 preserved from one generation to the next.(Watson 1984)(: 36)(Abbott 2012)(: section 1.2)

493

494 To use a modern analogy: It is common to find modern church bulletins in which the Psalm reading is
495 printed in the New International Version, yet the Lord's Prayer is printed in King James English. From
496 linguistic evidence alone, one might conclude that the Psalms are modern and the Lord's Prayer is 400
497 years older. But we know this is not the case: the Psalms predate the Lord's Prayer by a thousand years.

498 The Lord's Prayer is a beloved litany, learned "at their mother's knee" by children in King James
499 English. Generations of Christians have resisted modernizing the language of this familiar prayer.
500

501 CONCLUSIONS

502 The biblical crossing of the *yam suf* matches a wind setdown event at the eastern end of the Lake of
503 Tanis, where the Pelusiac branch of the Nile once flowed into a coastal lagoon at Tell Kedu. Exodus
504 14 holds up well under modern scientific examination. The narrative of parting the sea is a coherent
505 and plausible account of a little-known but well-documented hydrodynamic phenomenon. The
506 meteorological details given in the text are supported by ocean models and observations of similar
507 events that have occurred in modern times. Computer modeling reveals several potential crossing sites
508 that are supported by evidence from archaeology and linguistics. Analysis of the current flow and grain
509 size in the Kedu Gap reveals that Moses and the Israelites would be walking across coarse sand
510 instead of wallowing in deep mud.

511
512 Within the ancient biblical literature known as the Pentateuch, we have found an accurate description
513 of a wind setdown event. Many aspects of the narrative correspond to physical reality. Based on the
514 details contained within the text, Exodus 14 is more likely to be a historical recollection than a purely
515 invented tale. The narrative requires a knowledge of Egyptian topography and meteorology that would
516 be difficult to acquire without spending decades in that country. The historical interplay between the
517 narrative in Exodus 14 and the "Song of the Sea" in Exodus 15 may be resolved by distinguishing
518 between the ancient **content** present in both chapters, and the archaic **language** of Exodus 15..
519

520 These accounts in the book of Exodus are well worth the attention of biblical scholars who study how
521 the text of the Old Testament has been passed down through history, and who seek to illuminate the
522 origins of the many peoples of the Middle East.
523

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Tables

Name	Alternate name	Latitude (North)	Longitude (East)	Notes
Bubastis	Tell Basta	30.5722	31.5124	Southeast of modern Zagazig.
Damietta		31.4204	31.8075	
Daphnae	Tahpanhes	30.8606	32.1714	Earlier crossing of the Pelusiac branch.
Ebedah	Edjo of Seti	30.9413	32.4900	
Etham		30.5833	32.2667	Near modern Ismailia.
Gilbana		30.9305	32.4752	
Hebua I	Tjaru	30.9352	32.3669	New Kingdom fort.
Hebua II		30.9319	32.3800	
Kedua	Tell Qedua	30.9833	32.4755	Endpoint of the crossing (Exodus 15).
Kedua Gap		30.9812	32.4553	Proposed site of the crossing.
Migdol	T-78	30.9059	32.4415	Magdolum?
Mt. Sinai	Jebel Musa	28.5397	33.9733	The traditional location.
eastern paleolagoon		30.9450	32.4500	Visible on satellite photographs.
Pelusium	Tell el-Farama	31.0424	32.5400	Baal-Zephon?
Pi-hahiroth		30.9666	32.4234	Starting point for the Kedua crossing.
Tell Ahmer	Ahmar	30.8951	32.3727	
Tell Abu Sefeh		30.8606	32.3543	Starting point for Ballah Lakes crossing.
Tell el-Borg		30.9234	32.4126	Alternate site for Migdol.

526 **Table 1.** Decimal coordinates (in degrees) for locating and mapping the important sites. Derived from
527 Table 1 of Drews and Han (2010), with four sites added.

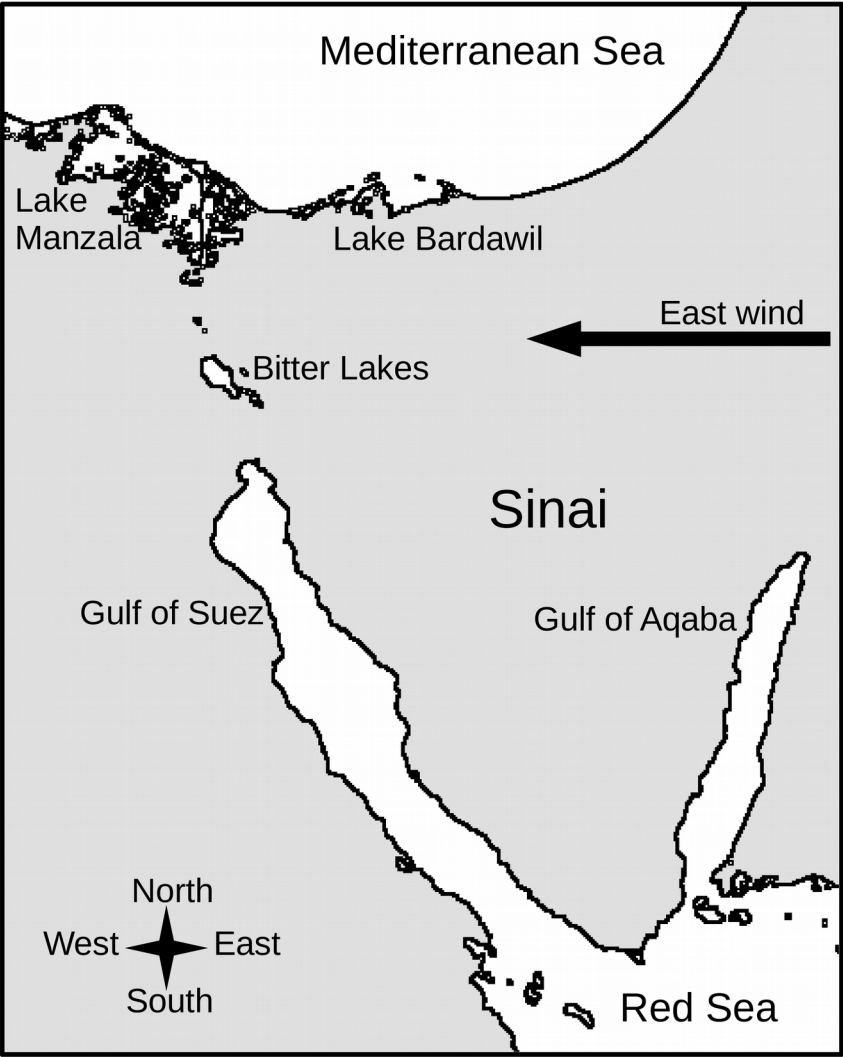
Crossing	Start	End	<i>yam suf</i>
Kedua	30.9666 N, 32.4234 E	30.9833 N, 32.4755 E	Lake of Tanis
Gilbana	30.9313 N, 32.4595 E	30.9298 N, 32.4737 E	eastern paleolagoon
Ahmer	30.8767 N, 32.3724 E	30.8734 N, 32.3889 E	Ballah marsh
Abu Sefeh	30.8602 N, 32.3568 E	30.8494 N, 32.3878 E	Ballah Lake

529 **Table 2.** The four crossing sites (in decimal degrees).

530

531

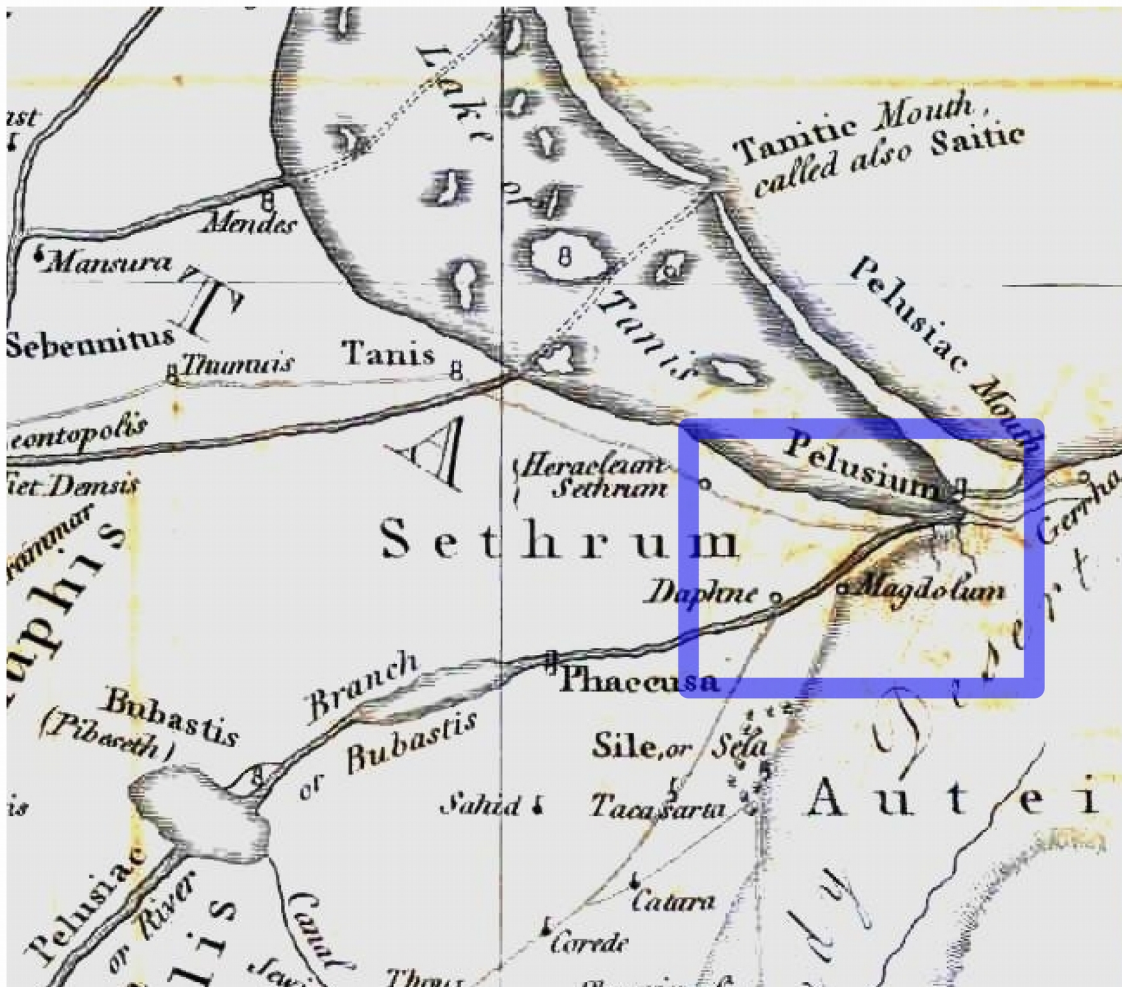
Figure Captions



532

533 **Figure 1. Bodies of water adjacent to Sinai.** Wind setdown has the greatest effect on shallow bodies
534 of water with a long extent in the direction of the wind. The most likely candidates for wind setdown
535 from an east wind are the lagoons along the Mediterranean coast (Manzala and Bardawil).

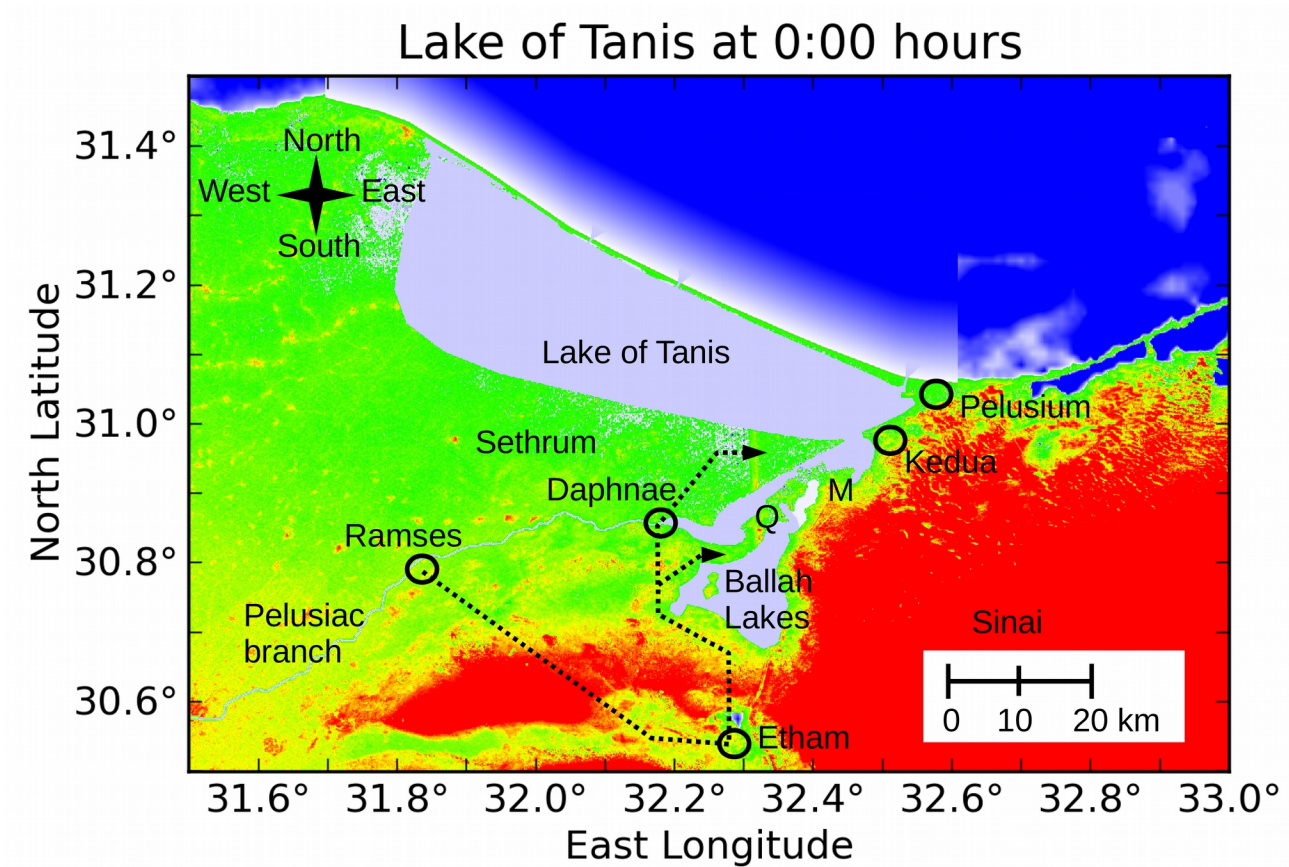
536



537

538 **Figure 2. James Rennell map of the northeastern Nile delta.** Rennell shows the Lake of Tanis
 539 (ancestral Lake Manzala) extending from Damietta to Pelusium, and separated from the open
 540 Mediterranean Sea by a line of sandy barrier islands. A strong east wind would cause drying at the
 541 eastern end of the lagoon (highlighted with blue rectangle).

542



543

544 **Figure 3. Reconstructed topography, with approaches to the crossing sites. Q = Qantara, M =**

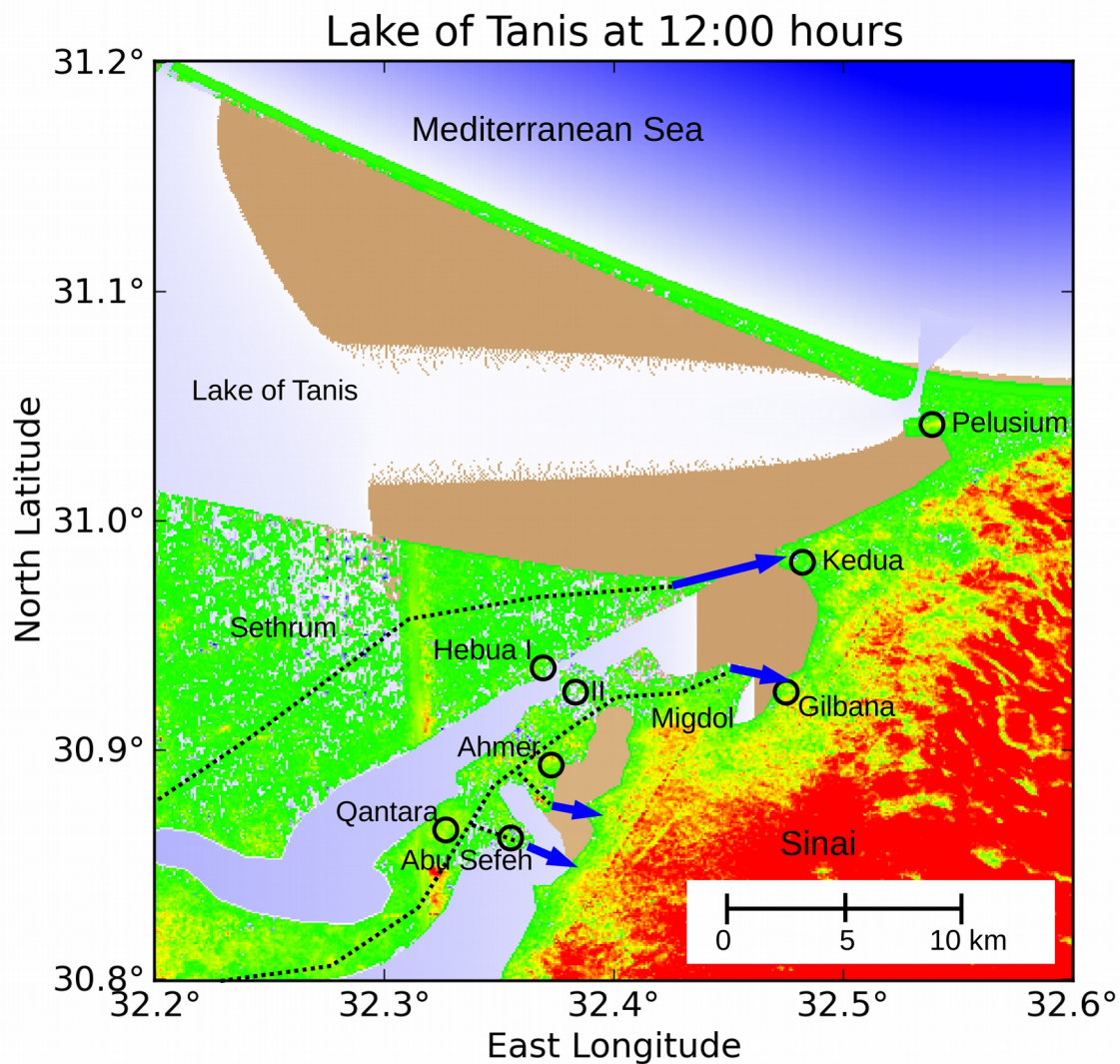
545 Migdol. The "traditional route" of the Exodus departs from Ramses heading southeast, then turns back

546 northward at Etham. Moses would approach the site of the sea crossing along the isthmus of Qantara or

547 farther north through Daphnae and the province of Sethrum. Derived from Figure 4 of Drews and Han

548 (2010), with New Kingdom sites and Exodus routes added.

549



550

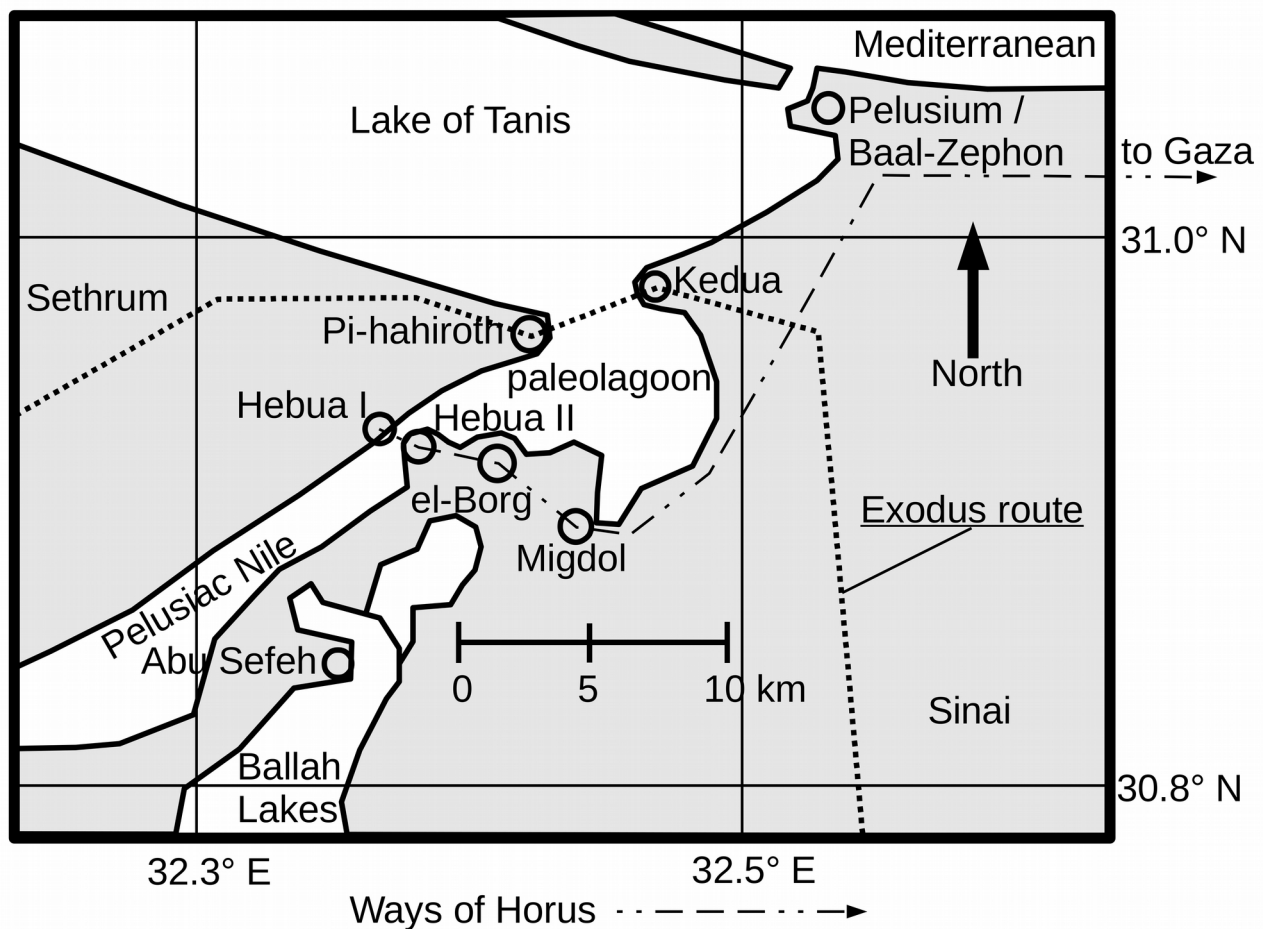
551 **Figure 4. Wind setdown in the Keduah Gap** at 12:00 hours under a wind blowing from due east
 552 (experiment T14). The four crossing sites are shown by blue arrows. Brown represents exposed mud
 553 flats or dry sand. Each crossing is an area of temporarily dry lake-bed where a multitude of Hebrews
 554 could escape eastward into the Sinai. At each site the alternate way around (on permanently dry land) is
 555 long enough so that Pharaoh's chariot force would be tempted to follow them into the sea. Note that a
 556 dry crossing from Abu Sefeh requires a wind direction of 40° north of due east (see the text in section
 557 Results). Derived from Figure 8 of Drews and Han (2010), with archaeological sites and crossing
 558 routes added.



560

561 **Figure 5. Blast of air drying wet cement.** An electric leaf blower (foreground) was placed on the
562 driveway near a garden hose in order to create a small-scale physical model of the Pelusiac Jet. The
563 entire cement surface was initially wet with water from the hose. A blast of air from the leaf blower
564 forced the stream of water to flow downwind instead of spreading out. After several minutes a dry
565 patch of cement was observed at the muzzle of the blower.

566



567

568 **Figure 6. Exodus route across the Kedia Gap**, bypassing the military "Ways of Horus". By careful
 569 route-finding and an unconventional sea crossing, the route through the Kedia Gap avoids the
 570 fortresses at Hebua, Tell el-Borg, and T-78 (Migdol). After crossing the *yam suf*, any route through the
 571 Sinai is feasible. Derived from Figure 3 of Drews and Han (2010), with Ways of Horus and Exodus
 572 route added.

573