Examining Exodus 14 with the Geosciences

Carl Drews
P.O. Box 3000
Boulder, Colorado USA 80307-3000
drews@ucar.edu

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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

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

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

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

The narrative in Exodus 14 has been identified as a wind setdown event since the late 1800s. In 1879 Samuel Bartlett suggested a crossing site in the shallows 4 km southeast of Suez (29.954° North, 32.569° East), based on local tales of wind and tide. (Bartlett 1879)(: 161, 179-182) Major-General Sir Alexander B. Tulloch personally witnessed a wind setdown event on Lake Manzala in 1882, when a strong east wind blew all night long and dried out the eastern end of the lake. (Tulloch 1896)(Drews 2011) Tulloch eventually concluded that the crossing took place between the Great Bitter Lake and Lake Timsah. In 1924 Bo Hellström constructed a wind tunnel and used it to investigate the physical processes behind the parting of the Red Sea. His experimental apparatus employed an underwater sill to model a crossing at Serapeum, between the Great Bitter Lake and Lake Timsah. (Hellström 1950) More recently Nof & Paldor and Voltzinger & Androsov used analytical techniques and a numerical model to analyze wind setdown at an underwater reef 10 km south of Suez (at 29.886° North, 32.546° East). (Nof and Paldor 1992)(Voltzinger and Androsov 2003) Colin Humphreys suggested wind setdown as the 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
Moses' gesture (held consistent throughout the plagues) from Moses stretching out his hand over the sea (Exod 14:16, 21) into Moses striking the water. (Josephus 94): 16.2) He adds 250,000 "horsemen" to the pursuing Egyptian force, in an era before the advent of military cavalry. Josephus reports the height of Mt. Tabor as 10x higher than it actually is (30 stades vs. 3 stades). (Maier 1999): 14) It falls beyond the scope of this paper to investigate all the discrepancies between the biblical account and the narrative of Josephus. This study is confined to what Josephus himself claims is his primary source: the text of the Hebrew Bible. (Josephus 94): 16.5) For this reason the present study considers only the narrative core of the sea crossing, which is Exodus 14.

Wind Direction

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

Is a biblical east wind blowing from the east, or toward the east? Exod 10:19 describes how the plague
of locusts ended: "And the Lord turned the wind into a very strong west wind, which lifted the locusts and drove them into the Red Sea [Hebrew yam suf]. Not a single locust was left in all the country of Egypt." [ESV] Although the location of the yam suf is not known for certain, all possibilities lie to the east of the Nile agricultural corridor. Only a wind blowing from the west could drive the locusts into the yam suf. From this verse we may conclude that the ancient author of Exodus used the same convention for wind direction that we use today; the compass point refers to the direction from which the wind is blowing. The wind direction is important for reconstructing the reported event.

A glance at the large bodies of water adjacent to the Sinai peninsula reveals that most of them are oriented north-south (Figure 1). The best candidates for an easterly wind setdown are the lagoons along the Mediterranean coast: Lakes Manzala and Bardawil. Lake Bardawil is along the "Way of the land of the Philistines" that was explicitly not taken (Exod 13:17). This leaves Lake Manzala. Kenneth Kitchen states that the marshy region of shallow lakes along the isthmus of Suez is an acceptable location for the Hebrew term "yam suf." (Kitchen 2003): 261-263) The "yam suf" is not confined to the modern Red Sea. (Hoffmeier 2005): 81-85)(Propp 1999): 486-487)

Zech 10:10-11 contains another reference to a miraculous passage through the Nile river:

10 I [the Lord] will bring them [the house of Judah] home from the land of Egypt, and gather them from Assyria, and will bring them to the land of Gilead and to Lebanon, till there is no room for them. 11 He [Judah] shall pass through the sea of troubles and strike down the waves of the sea, and all the depths of the Nile shall be dried up. The pride of Assyria shall be laid low, and the scepter of Egypt shall depart. [ESV]
Zech 1:1 states that the book takes place during the reign of Darius I of Persia, and therefore the immediate message of chapter 10 is directed to the Jewish exiles returning from Babylonian captivity. Nevertheless, prophetic images are sometimes repeated in biblical literature (see Isa 7:14 and Matt 1:23, Hos 11:1 and Matt 2:15). The promise of deliverance to the Babylonian captives would be strengthened by evoking memories of their ancient deliverance from slavery in Egypt. Thus there is some limited support in Zechariah for a geographical context of the crossing associated with the Nile river.

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

Reconstructing the Lake of Tanis

The eastern Nile delta is subject to a mix of geological processes that is different from those of other sections of the eastern Mediterranean coast. Geologist Jean-Daniel Stanley has shown that although the eastern delta has subsided, recent tectonic uplift along the Pelusium Line fault has preserved this
sandstone ridge above worldwide sea level rise, along with the New Kingdom (c. 1550 BC - 1070 BC) sites on top of it and to the south. (Stanley et al. 2008) Huge plumes of sediment from the Nile mouths, swept toward the east by alongshore currents and waves, have also expanded the coastline seaward. Thus the Roman ruins and harbor at Pelusium are not submerged beneath the Mediterranean Sea, but are above sea level and farther from the shore than when they were constructed. Stanley's geological research allows us to reconstruct the geography of the eastern delta with assurance that these sites were coastal and habitable during the Exodus time period.

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

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

In 1800, oceanographer James Rennell created a map of the ancient delta during the Greek classical period based on the writings of Herodotus. (Rennell 1830) The Rennell map is a useful schematic (Figure 2). It shows the Pelusiac branch of the Nile flowing eastward from Cairo, and emptying into the Mediterranean at Pelusium. Of particular interest is Rennell's depiction of the Lake of Tanis, a large coastal lagoon separated from the open sea by a line of coastal barrier islands.
The Lake of Tanis (ancestral Lake Manzala) is not shown on most archaeological maps, but its presence is supported by evidence from geology, (Stanley and Warne 1993) (Stanley et al. 1996) oceanography, (Drews and Han 2010) and papyrus Chester Beatty II. (Drews 2009) This protected, shallow lagoon would have been susceptible to strong winds blowing from the east. Over a period of several hours these winds would produce large areas of exposed lake bed on Egypt's eastern frontier. This is a possible location where Moses and the Hebrews were trying to pass through. Table 1 shows important New Kingdom sites in the vicinity.

**ROMS Ocean Model**

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

The Regional Ocean Modeling System (ROMS) is a computer model that simulates the effect of wind on this domain. The wind velocity is 28 meters per second, comparable to a medium-strength tropical storm on the Saffir-Simpson hurricane scale. This digital wind is programmed to blow for 12 hours -
"all that night" according to Exod 14:21 - and then stop. The model continues to run for another 12 hours. (Drews and Han 2010)

RESULTS

Four Crossing Sites

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

The crossing at Kedua is the most spectacular, reaching from the eastern end of the Sethrum peninsula across to the bluff at Tell Kedua about 3 km away. Exodus 14, verses 22 and 29, specify a curious hydrodynamic detail: water was present on both sides of the crossing. As shown in Figure 4, a group of people standing at the eastern end of Sethrum and facing east would see water on their left side (north), on their right side (south), while a dry passage would be open ahead of them (to the east). This division of waters occurs because the confluence of the Pelusiac branch and the Lake of Tanis forms an angled curve in the combined body of water, and the Sethrum peninsula splits this body as the water shifts to the west under wind stress. (Drews and Han 2010) The water to the north of the Kedua Gap is a high-velocity stream 20 cm deep that issues from the Pelusiac mouth of the Nile at Pelusium. The strait at the Kedua Gap becomes completely dry at 9:24 hours and refills at 13:24 hours, for an elapsed crossing time of 4.0 hours (experiment T14). The dry passage is 4 km wide at 12:00 hours. A follow-up
study calculated a dry crossing time of about 8 hours. (Drews 2013)

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

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

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

Tell Abu Sefeh is another waypoint along the isthmus of Qantara, between Avaris and the eastern frontier. Here a small peninsula extends into the northeast arm of the Ballah Lakes. Because the primary axis of the Ballah Lakes is not strictly east-west, a dry crossing at Abu Sefeh requires a wind blowing from 40° north of due east (experiment T6). This wind direction is acceptably east by the Hebrew narrative compass. The Ballah Lakes are just barely long enough in this direction (25 km) to
generate a wind setdown of 2 meters. The crossing at Abu Sefeh retains water only on the right (southern) side, although there may be small pockets of water remaining north of Abu Sefeh that the ROMS grid cannot resolve. This passage opens at 9:18 hours and closes at 12:06, for an elapsed crossing time of 2.8 hours.

Walls of Water

Many depictions of the Red Sea crossing in popular culture portray an event with standing vertical walls of water on either side of the crossing party. The study of fluid mechanics tells us that after the wind ceased, the return wave would behave like a tidal bore,(Kundu and Cohen 2004) and would appear as an advancing wall of water to any soldiers trapped in the crossing. However, the scenario presented here does not provide for stationary vertical walls of water during the crossing. The English word "wall" in Exod 14:22 is Hebrew "chowmah". HALOT defines "chowmah" as "1. city wall; 2. wall around building or area of city; 3. metaphor: wall of water."(Koehler and Baumgartner 2001) They give Exod 14:22-29 and 1 Sam 25:16 as examples of metaphorical usage. Brow, Driver, and Briggs (BDB) note that "chowmah" carries the idea of protection.(Brown, Driver, and Briggs 1906) "Chowmah" in Exodus 14 is the metaphorical description of a protective barrier for Moses and the Israelites; the waters on either side of the passage guarded against flank attack by the pursuing chariot army.(Bartlett 1879) This interpretation is in accord with similar usage in Nah 3:8 "Are you better than Thebes [No-amon] that sat by the Nile, with water around her, her rampart a sea, and water her wall?" [ESV]. Although the same Hebrew word is used in both passages, no biblical scholar claims that the Nile river stood up in a vertical wall as it flowed past Thebes. Instead, the Nile and its canals formed a protective moat around the city.
Dry Ground and Chariot Wheels

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

Yet Exodus 14 verse 25 states that the wheels of Pharaoh's chariot wheels were "clogged" so that they "drove heavily". The Samaritan Pentateuch and the Septuagint report in verse 25 that the chariot wheels fell off. Taken together, these verses pose a physical problem: How could the bottom of a muddy lagoon be made firm enough to walk upon, yet prevent wheeled vehicles from traveling across the same surface? The Tulloch account mentions that "the natives were walking about on the mud" of the exposed bottom of Lake Manzalah, (Tulloch 1896) and from this report we may presume that the mud flats at his location were at least passable on foot. However, the model results from Drews and Han (2010) can provide a more quantitative answer to this question.
The Kedua Gap represents a strait between the eastern paleolagoon and the Lake of Tanis to the north. This strait restricts the water flow and increases the current speed. Tanis experiment T4 models the Kedua Gap at its lowest water level, beginning with the lagoon in a quiescent state, with no influence from winds or tide throughout the model run. The only flow source in T4 comes from the Pelusiac branch during the spring season. (Drews and Han 2010) Experiment T4 shows the current in the strait stabilizing at about 2 cm/sec. This value represents the lowest current flow in the area of the crossing that we would ever expect without even minimal wind or tidal forcing.

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

Let us consider a more normal range of current flow by selecting from the extreme range a central subset. Since the relationship between water flow and sediment size is logarithmic, the central third of the range 2 - 30 cm/sec is calculated from the log of the current to be: 5 - 12 cm/sec. This subset should represent the range of current flow during a normal year of the Nile river. The Hjulström curve between transport and deposition shows that the grain size for this range of currents is 0.9 mm - 2.5 mm. (Hjulström 1939) Filip Hjulström defines "coarse sand" as having a diameter of 1 mm or greater. (p. 21) Thus Moses and the Israelites would be walking not through silty mud, but across coarse sand. The author has found informally that the coarse sand of a volleyball court is easy to walk across but difficult
to traverse on a commuter bicycle. Note that for the extreme current range the Hjulström curve gives values for the grain size of 0.3 - 12 mm (medium sand - pebbles).

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

**DISCUSSION**

Exod 14:1-2 records very specific directions: "Then the Lord said to Moses, 'Tell the people of Israel to turn back and encamp in front of Pi-hahiroth, between Migdol and the sea, in front of Baal-zephon; you shall encamp facing it, by the sea.'" [ESV] "Between Migdol and the sea" is a key phrase for locating the famous crossing. James Hoffmeier has provisionally identified the archaeological site T-78, at the southern end of the eastern paleolagoon, as Migdol of the Exodus narrative. (Hoffmeier 2005)(: 105) The nearby site Tell el-Borg is another possibility, or perhaps the entire area of the two sites could be
viewed in the context of Exod 14:2 as "the Migdol cluster". If this identification is correct, then all four of the crossing sites revealed by the ROMS ocean model are in some way located "between Migdol and the sea". They are all within 10 km of Migdol, and they all have some large body of reedy water in the opposite direction. Thus ocean modeling represents an independent line of evidence supporting Hoffmeier's identification of Migdol with either T-78 or Tell el-Borg. Table 2 shows the four crossings and the implied bodies of water through which Moses would pass.

**Exodus Route**

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

The ROMS model supports the interpretation by Propp, Kitchen, HALOT, and BDB that the Hebrew word "shuwb" for "turn back" in Exod 14:2 means not merely a course correction, but a reversal and a return back toward the original position. (Propp 1999): 490)(Kitchen 2003): 259-260)(Koehler and Baumgartner 2001): 1427)(Brown, Driver, and Briggs 1906) "Shuwb" is used in Exod 14:26, 27, and 28 to describe the water flowing back to its natural seabed by gravity after the wind had stopped, as the hydraulic model shows. Turning northward at Etham would set Moses back on a course toward his starting location at Ramses. Although a move back north from Etham seems illogical for a party intending to avoid the Mediterranean coastal route, the biblical text indicates that this was indeed the
A crossing at Kedua would require Moses and the Hebrews to cross the Pelusiac branch of the Nile from south to north at the site later called Daphnae, then proceed to the eastern end of the Sethrum peninsula along the marshy southern shore of the Lake of Tanis. This route has the advantage of bypassing the Migdol fortified zone (Hebua, el-Borg, T-78) to the west and north. The eastern tip of Sethrum would likely be unguarded, as the ancient Egyptians would consider 3 kilometers of water to be an impenetrable barrier to walking refugees. There is room here for an armed standoff between two large groups of people. After the crossing, any route across the Sinai would be open to Moses and his company (Figure 6).

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

The crossings at Ahmer and Abu Sefeh would require any company of Hebrew refugees to approach the Migdol fortified zone from the southwest, but not enter it. In both cases the final encampments would be at small promontories on the eastern side of the Qantara road, facing across the northeastern lobe of the Ballah Lakes. These sites have a significant drawback in that they do not exhibit water on both sides of a dry passage, and so do not match the biblical narrative.
Exod 13:17 states that the Hebrews did not take the "way of the land of the Philistines", because this northern coastal route was fortified. Hoffmeier (2005: 65-6) equates this route with the "Ways of Horus", meaning that the forbidden road began at Tjaru (Hebua I) and ended at Gaza. I suggest that since the Waters of Horus are confined to the eastern Nile delta, and the Philistine terminology reflects the later perspective from Canaan; then the "Ways of Horus" signified the military road west of the site later known as Pelusium (27 km), while the "way of the land of the Philistines" referred to the longer section from Pelusium to Gaza (170 km). Since none of the four crossings require travel eastward beyond Pelusium, Exod 13:17 would be satisfied if the verse refers only to the road beyond the eastern Nile delta.

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

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

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

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

During the New Kingdom period, the Pelusiac branch of the Nile served as a canal for transportation and irrigation, bringing water to the eastern delta region. The Pelusiac emptied into the Lake of Tanis through the Kedua Gap. Stephen Moshier and Ali El-Kalani have also identified a canal passing through Tell el-Borg and emptying into the eastern paleolagoon. (Moshier and El-Kalani 2008)

Thus there are at least two canal mouths at Kedua that would satisfy the meaning of "Pi-hahiroth". During the Exodus period Pi-hahiroth was possibly just a place name, or a small fishing settlement, at the eastern end of the Sethrum peninsula. The archaeological site Tell el-Ghaba here is dated to the early Saite period, 26th dynasty (600 BC). (Goyon 2007)

I have placed Baal-Zephon at the site later known as Pelusium, based on its location on the Rennell map. At the time of the Exodus this cape was rising above sea level due to uplift by tectonic forces. (Stanley et al. 2008) I understand the phrase "facing Baal-Zephon" to mean "looking out across the water toward Baal-Zephon in the distance." Pelusium is a prominent landmark in just the right place; it would be visible from the tip of the Sethrum peninsula, pulling the Hebrews' gaze eastward toward freedom. Perhaps there was a Canaanite shrine to Baal there. Yet the Exodus text never describes Moses actually reaching Baal-Zephon. The Rennell map shows ample room for the refugees to cross southeast from the tip of Sethrum, celebrate their deliverance (Exodus 15), and then flee southward into the Sinai wilderness, all without quite passing through Pelusium.

The geological research by Moshier and El-Kalani (2008) greatly clarifies the topography at the
Pelusiac mouth of the Nile. Although Tell Kedua and Tell el-Herr are also across the water from Pi-hahiroth, they were not occupied until after the Exodus, (Hoffmeier 2005): 95-96 and so are unlikely to be cited in the triangulation of Exod 14:1-2. The New Kingdom site of Tell Ebedah is another possibility for Baal-Zephon, again based on its location across the water to the east.

**Ta-denit: The Dividing Waters**

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

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

I propose that the English phrase "the dividing waters" is correct, but may not carry the meaning that Gardiner intended. Instead, Ta-denit refers to the dividing waters because these waters themselves divide when strong winds blow from the east. The Egyptian phrase Ta-denit would then preserve the
local memory of an unusual phenomenon that occurred at the eastern paleolagoon perhaps once every
generation. The geographical toponym "the dividing waters" was given in antiquity to the lagoon and
the Pelusiac Nile at Hebu to signify their remarkable behavior whenever a gale swept in from the
Arabian desert. The waters separated around the peninsula at Pi-Hahiroth, east of Hebu and north of
Migdol. Moses may have been aware of these tales; in any case, the meteorological phenomenon would
have been rare enough that neither he nor the pursuing chariot force could know for certain what was
going to occur.

Exodus 15 - The Song of the Sea

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

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

Kenneth Kitchen disagrees with this general principle:

This [example involving the Exodus plagues] illustrates a basic literary phenomenon endemic to
the ancient Near East, yet one constantly abused by biblicists. When prose and poetry accounts
coexist, it is prose that is the primary source and poetry that is the secondary celebration. This
cannot be overstressed. (italics original)

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

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

To use a modern analogy: It is common to find modern church bulletins in which the Psalm reading is printed in the New International Version, yet the Lord's Prayer is printed in King James English. From linguistic evidence alone, one might conclude that the Psalms are modern and the Lord's Prayer is 400 years older. But we know this is not the case: the Psalms predate the Lord's Prayer by a thousand years.
The Lord's Prayer is a beloved litany, learned "at their mother's knee" by children in King James English. Generations of Christians have resisted modernizing the language of this familiar prayer.

CONCLUSIONS

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

Within the ancient biblical literature known as the Pentateuch, we have found an accurate description of a wind setdown event. Many aspects of the narrative correspond to physical reality. Based on the details contained within the text, Exodus 14 is more likely to be a historical recollection than a purely invented tale. The narrative requires a knowledge of Egyptian topography and meteorology that would be difficult to acquire without spending decades in that country. The historical interplay between the narrative in Exodus 14 and the "Song of the Sea" in Exodus 15 may be resolved by distinguishing between the ancient content present in both chapters, and the archaic language of Exodus 15.
These accounts in the book of Exodus are well worth the attention of biblical scholars who study how the text of the Old Testament has been passed down through history, and who seek to illuminate the origins of the many peoples of the Middle East.

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<table>
<thead>
<tr>
<th>Name</th>
<th>Alternate name</th>
<th>Latitude (North)</th>
<th>Longitude (East)</th>
<th>Notes</th>
</tr>
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<td>30.5722</td>
<td>31.5124</td>
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<td>31.4204</td>
<td>31.8075</td>
<td></td>
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<td>Daphnae</td>
<td>Tahpanhes</td>
<td>30.8606</td>
<td>32.1714</td>
<td>Earlier crossing of the Pelusiac branch.</td>
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<td>Edjo of Seti</td>
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<td>32.2667</td>
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<td>Tjaru</td>
<td>30.9352</td>
<td>32.3669</td>
<td>New Kingdom fort.</td>
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<td>T-78</td>
<td>30.9059</td>
<td>32.4415</td>
<td>Magdolum?</td>
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<td>Jebel Musa</td>
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<td>33.9733</td>
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<td>30.9450</td>
<td>32.4500</td>
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<td>Baal-Zephon?</td>
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Table 1. Decimal coordinates (in degrees) for locating and mapping the important sites. Derived from Table 1 of Drews and Han (2010), with four sites added.
<table>
<thead>
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<th>Crossing</th>
<th>Start</th>
<th>End</th>
<th><em>yam suf</em></th>
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<td>30.9833 N, 32.4755 E</td>
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<td>30.9298 N, 32.4737 E</td>
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<td>Ahmer</td>
<td>30.8767 N, 32.3724 E</td>
<td>30.8734 N, 32.3889 E</td>
<td>Ballah marsh</td>
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<tr>
<td>Abu Sefeh</td>
<td>30.8602 N, 32.3568 E</td>
<td>30.8494 N, 32.3878 E</td>
<td>Ballah Lake</td>
</tr>
</tbody>
</table>

Table 2. The four crossing sites (in decimal degrees).
Figure 1. **Bodies of water adjacent to Sinai.** Wind setdown has the greatest effect on shallow bodies of water with a long extent in the direction of the wind. The most likely candidates for wind setdown from an east wind are the lagoons along the Mediterranean coast (Manzala and Bardawil).
Figure 2. James Rennell map of the northeastern Nile delta. Rennell shows the Lake of Tanis (ancestral Lake Manzala) extending from Damietta to Pelusium, and separated from the open Mediterranean Sea by a line of sandy barrier islands. A strong east wind would cause drying at the eastern end of the lagoon (highlighted with blue rectangle).
Figure 3. Reconstructed topography, with approaches to the crossing sites. $Q = \text{Qantara}, M = \text{Migdol}$. The "traditional route" of the Exodus departs from Ramses heading southeast, then turns back northward at Etham. Moses would approach the site of the sea crossing along the isthmus of Qantara or farther north through Daphnae and the province of Sethrum. Derived from Figure 4 of Drews and Han (2010), with New Kingdom sites and Exodus routes added.
Figure 4. Wind setdown in the Kedua Gap at 12:00 hours under a wind blowing from due east (experiment T14). The four crossing sites are shown by blue arrows. Brown represents exposed mud flats or dry sand. Each crossing is an area of temporarily dry lake-bed where a multitude of Hebrews could escape eastward into the Sinai. At each site the alternate way around (on permanently dry land) is long enough so that Pharaoh’s chariot force would be tempted to follow them into the sea. Note that a dry crossing from Abu Sefeh requires a wind direction of 40° north of due east (see the text in section Results). Derived from Figure 8 of Drews and Han (2010), with archaeological sites and crossing routes added.
Figure 5. Blast of air drying wet cement. An electric leaf blower (foreground) was placed on the driveway near a garden hose in order to create a small-scale physical model of the Pelusiac Jet. The entire cement surface was initially wet with water from the hose. A blast of air from the leaf blower forced the stream of water to flow downwind instead of spreading out. After several minutes a dry patch of cement was observed at the muzzle of the blower.
Figure 6. Exodus route across the Kedua Gap, bypassing the military "Ways of Horus". By careful route-finding and an unconventional sea crossing, the route through the Kedua Gap avoids the fortresses at Hebua, Tell el-Borg, and T-78 (Migdol). After crossing the *yam suf*, any route through the Sinai is feasible. Derived from Figure 3 of Drews and Han (2010), with Ways of Horus and Exodus route added.