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# Enhanced Mathematical Method for Visualizing Ptolemy's Arabia[1]

*Summary*: In this article, we provide updates and enhancements to the mathematical methods for translating ancient coordinates from Ptolemy's classical *Geography* into coordinates that can be used in modern GIS tools, such as ArcGIS, QGIS, and Google Earth. We also expand our coverage from India to Arabia, another historically important peninsular subcontinent of Asia. The enhancements we have made include novel techniques for identifying duplicates and handling tentatively identified points, instead of just known and unknown ones, surrounding the region of interest by known points from adjacent regions, and modifications to our two primary underlying models, triangulation and flocking. We compare the precision of reconstruction achieved for Ptolemy's Arabia with the precision that we had computed earlier for his India before the Ganges. We also provide improved validation and comparison amongst the methods applied. The combination of these enhancements with the expansion of our coverage to Arabia as described by Claudius Ptolemy represents a novel contribution to understanding of our cultural cartographic heritage by improving our ability to explore the ancient world using familiar and accessible GIS tools.

## Introduction

This paper presents continuation of our multi-year study of the classical *Geography* by Claudius Ptolemy, a unique source that provides coordinates of 6,300+ locations known to the ancient scientist. These locations comprise capital cities, towns, villages, markets, harbors, anchorages, capes, bays, mountains, islands, boundary marks (termini), lakes, river sources, mouths and bends, etc. Ptolemy supplemented his catalog with useful descriptions and other important information, such as the names of the legions that were stationed in certain cities and the names of the numerous tribes that once inhabited the vast territory of Europe, Africa, and Asia. In this work, we extend the scope of our research to Arabia, while refining our methods of numerical analysis of historical data previously applied to Ptolemy's West Africa (Filatova et al. 2019) and most of India (Abshire et al. 2015). A detailed review of the scientific literature relevant to the analysis of Ptolemy's Arabia is provided in the next section.

Even though Claudius Ptolemy left us a rich and very valuable catalog, its interpretation and visualization pose a formidable challenge to the modern researchers, due to significant distortions of the true shape of the known world and the complications introduced by Ptolemy's book being a compilation. As a result, a lot of painstaking and diligent work is required to unveil the informational treasures of the ancient source and present the finds in a form convenient for the modern reader and viewer of maps. In this article, we deal with 300+ places found in Arabia, a large region subdivided by Ptolemy into three provinces — Arabia Petraea, Arabia Deserta, and Arabia

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Felix. The nature of the data forced us to extend our approach to point identification. Instead of just dividing the points into known and unknown ones, we introduce a new category of tentatively identified points, along with a separate category for duplicates. Following and extending our computational methods previously applied to Ptolemy's India, we then approach the problem of approximate placement of the points that could not be positively or even tentatively identified and georeferenced. The part of India that we dealt with before is confined conveniently by its shores, the borders of the valleys of the Indus and Ganges rivers, and the Himalayas (Imaus Mountains). Taprobane (the modern Sri Lanka) is an island. Even though, like India, Arabia occupies a large peninsula, we need to surround the northern part of it with known points from the adjacent Ptolemaic provinces of Judaea Palestina, Syria, Mesopotamia, and Babylonia, in order to make our triangulation method with Bayesian adjustment work well. This important time-consuming task is covered in the third section of the article.

The fourth section of the paper is devoted to the modification of the flocking method, our second numerical technique for approximate placement of points that was first tried on the India data set. A change in the formula for the computation of weights for the point's neighbors yields an incremental improvement over the original approach.

The essential initial step that involves identifying and georeferencing as many places as possible prior to applying the digital techniques for approximate placement is quite complicated. We discuss it in the fifth section.

We anticipated that the precision of numerical reconstruction that our methods can achieve would vary from region to region, according to the quality and quantity of knowledge about each region supplied by the ancient author, and in line with our own ability to identify and georeference points in the region. In the sixth section of our work, we compare the precision of reconstruction achieved for Ptolemy's Arabia with the precision that we had computed earlier for his India before the Ganges. The data for the flocking method for India is updated to reflect the newly introduced change.

We draw conclusions and outline the future research directions in the final section of the article.

**Literature Review**

The best available complete modern translation of Ptolemy's *Geography*, the preparation of which involved comprehensive comparison of several Greek manuscripts, is the German translation by Stückelberger and Grasshoff (2006). It also supplies an authoritative Greek version of the original text. We used the electronic database of coordinates that accompanies the book and adopted its object IDs. Stückelberger and Grasshoff also suggest modern names for many locations mentioned by Ptolemy. However, in Arabia and the neighboring provinces their identifications often originated from the notes in a much earlier work by Müller (1883-1901). The quality of the only complete English translation by E. L. Stevenson (Ptolemy 1991) is known to be poor (Diller 1935). In particular, many toponyms in that translation are latinised unnecessarily. Nonetheless, we did use this source, along with the Greek original, to translate the German names into English, with minimum latinisation, given that very few if any of the toponyms found in Arabia were of Latin origin to begin with.

We found that the best two sources for point identification were the beautifully printed (Talbert 2000) and the online (Åhlfeldt 2017). They provided excellent coverage of Arabia Petraea and the rest of the ancient Nabataean kingdom. However, their precision in South Arabia often proved insufficient, and the latter of the two sources did not covered all of Arabia's territory. Also, the

ancient names preferred by these sources often deviate from the Ptolemy ones. Along the shores of South Arabia, the *Periplus of the Erythraean Sea* (Schoff 1912) proved a good guide, just like it did in the Western part of India before the Ganges.

We consulted with such classic sources on ancient Arabia as (Bonne 1771), (d'Anville and Horlsey 1791), (Robinson and Smith 1841), (Forster 1844), (Colton 1855), (Kiepert 1856), (Spruner 1865), (Johnson 1870), (Sprenger 1875), and (Dougherty 1930).

Useful modern publications relevant to the subject include (Bowersock 1971), (Brice 1974), (Potts 1984), (Groom 1986), (Munro-Hay 1991), (Potts 2001), (Beech 2004), (Almutairi 2011), (Izaksen 2012), (Haerinck 2012), and (Görsch 2017).

Among the publications that do not deal with Arabia, yet provide better understanding of Ptolemy's rationale and methods, we must name the monograph by Berggren and Jones (2000), which presents a nearly complete reconstruction of Ptolemy's Gallia, the comprehensive catalog by Tsorlini (2011) covering Ptolemy's Mediterranean and Black Sea region, and an article by Graßhoff et al. (2017) on the methods that Ptolemy may have applied to derive his coordinates. Numerous references to other publications devoted to the mathematical analysis of ancient maps can be found in the literature review included in our paper on Ptolemy's India (Abshire et al. 2016).

## Surrounding Arabia

While we do know some of the modern equivalents of places in Arabia that Ptolemy mentions, very many of them remain unknown, especially in Arabia Felix. Our *triangulation model* (Abshire et al. 2016) uses three Ptolemaic points for which we know their modern coordinates to form a spherical triangle surrounding a point to be predicted, and then triangulate to find the unknown point. A similar, but not identical *method of azimuths*, also based on using three nearby points, was introduced by Manoledakis and Livieratos (2006). Unlike their method that employs difference vectors, our technique using spherical triangles is less sensitive to distortions caused by rotation, so it has been to shown to perform reasonably well in a more general setting. However, the restriction that each of the unknown places to be predicted must be enclosed by a spherical triangle formed by known points poses a problem for many points located on the borders of the area under investigation.

In order to remedy this problem for Arabia, we surrounded its northern part with the known points from Ptolemy's Judaea Palestina, Syria, Mesopotamia, and Babylonia, which can be seen in Figures 1 and 2. For Arabia Felix, the known points from Arabia Petraea and Arabia Deserta came in handy. The unknown points that still weren't enclosed by spherical triangles after that were processed using a modified *flocking model* (Abshire et al. 2016). We will discuss our modification of the flocking model in the next section of the article.

In addition to that, we post-processed the results using our *Bayesian adjustment* technique developed for India (Abshire et al. 2016) with the prior for Arabia shown in Figure 1. By accepting the maximum probability points within the prior, we have assured that the points located near the coastline were not placed in the sea. We have also eliminated the possibility of the unknown points' crossing over to Iran. Islands have to be taken into account carefully when the Bayesian correction is applied.

In our computation of the areas of spherical triangles in Ptolemy's coordinate systems, we applied a special *narrowing coefficient γ* to the longitudinal differences in order to account for Ptolemy's underestimation of the length of equator. This underestimation is unevenly distrib-

uted region-to-region (Filatova et al., 2019). The value of the narrowing coefficient for Arabia was derived from the longitudinal differences between Palmyra (Tadmor) and Susa (Shush). It was computed as (48.2469-38.2701)/(84.0 − 71.5) ≈ 0.8.



Figure 1. The Bayesian calculation prior for Ptolemy's Arabia.

**Flocking Modification**

In our *flocking model* (Abshire et al. 2016), we take the $k$ known nearest neighbors of the unknown point $y_p$, use their respective distances from the unknown point to compute weighted average of the movement, and use this average to move the unknown point so that it becomes its modern match

$$y_m = y_p + \sum_{i=1}^{k} v_i w_i$$

where y is the predicted point vector $\lambda_m$ and $\varphi_m$, $v_i$ is the difference of the $i^{\text{th}}$ nearest neighbor of $y$'s $k$ neighbors of its modern coordinate to its Ptolemy coordinate, and $w_i$ is the weight for the $i^{\text{th}}$ neighbor. The flocking model is selected as an alternative and complement to the triangulation model, because the unknown points are not required to be enclosed by a spherical triangle of known points here.

In our newly corrected version of the algorithm, the weight for each neighbor is computed as

$$w_i = \frac{\sum_{j=1}^{k} d_j - d_i}{(k-1)\sum_{j=1}^{k} d_j}.$$

This way we assure that the unknown point "tracks" its closer known neighbors to a greater extent than the ones that are situated relatively far away from it. This correction represents an incremental improvement over the original, faulty formula for the weights that had it the other way around.

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# Point Identification

In the course of our earlier work on Ptolemy's India, we mostly used just one other source (McCrindle 1927) to fill the gaps left by Stückelberger and Grasshoff. In that situation, it was reasonably appropriate to divide the Ptolemaic locations into two categories — *known* and *unknown* points. That additional source was specific to India, so it did not cover Arabia. As we began to deal with Arabia, relatively many sources contributed to our decision process, sometimes contradicting each other. For example, unlike Talbert, Åhlfeldt, Stückelberger and Grasshoff, we take Ptolemy's Baitios River (commonly latinised as Betius) to correspond to Wadi Fa'idah, or Wadi Fayd, a stream that passes by the village of Fa'idah, or Fayd, on its way toward a harbor called Khawr al Buṯān. This choice corresponds to the earlier one made by d'Anville and Horsley, who identified Betius as the streams then known as the Bardilloi. From Bonne's map, it is quite clear that one of the Bardilloi is the modern Wadi Fa'idah. Sprenger disagreed with d'Anville and Horsley on this matter and "moved" Betius approximately 630 km south to another suitably named stream, Wadi Baysh. Nevertheless, Sprenger still identified the nearby city of Macoraba as Mecca. Meanwhile, the town of Lathrippa, which Ptolemy places to the northeast from the mouth of the Baitios River, is positively identified by Sprenger as the ancient Yathrib (or Yatreb), the modern Medina, renamed al-Madīnatu n-Nabī ("the city of the prophet") after Prophet Muhammad during the Islamic era. Surprisingly, Stückelberger and Grasshoff miss this identification, even though Talbert and Åhlfeldt agree with it, having corrected the ancient name to read "Iathrippa." We chose to maintain the relative proximity of the Baitios River to both Mecca and Medina, instead of assuming a gross error by Ptolemy for no good reason. Gibson (2013) misidentifies Ptolemy's Betius River as Wadi Mawr in Yemen, approximately 780 km south from Wadi Fa'idah, shifts many points south using a simplistic mathematical formula, and takes Macoraba to be the modern city of Marib in Yemen. The latter is actually Ptolemy's Mara, alternatively written in some manuscripts as Marama, Baraba. Stückelberger and Grasshoff correct these misspellings to mean "Maraba." Gibson also misplaces Ptolemy's Prion River (latinised Prionis) to mean Wadi Dhahawn (Tīkhawn) that enters the Indian Ocean near the town of Al Ghaydah under the name Wādī al Jiz'. By this, he misses the significant Wadi Ḥajr located not far from Ptolemy's city of Mepha (ruins near the modern town of Mayfa'ah) by approximately 450 km. Gibson also mistakenly takes Ptolemy's Lar River (latinised as Laris) to be Dubai Creek, but it is actually the much longer Wadi al Baṯḥā' 60 km away, also known upstream as Wadi Lamḥah. Like Stückelberger and Grasshoff before him, Gibson is unaware of the aforementioned certain identification of Ptolemy's Lathrippa as the modern Medina, and his mathematical manipulations lead, in particular, to Ptolemy's inland town of Mochura being superimposed over the modern Yenbu, or Yanbu, Ptolemy's Iambia village, a readily identifiable coastal place. In spite of these critical comments, we do agree with Gibson's identification of Ptolemy's Ormanus (Hormanus) River as Wadi Bani Khalid, a long and important stream in Oman that maintains a constant flow of water all year long. At its mouth, it is known as Batha River.

Talbert and Åhlfeldt routinely expressed uncertainty about their identifications, especially in Southern and Eastern Arabia. As a result, we found it appropriate to introduce the category of *tentatively identified* points. Meanwhile, in our maps of Ptolemy's India before the Ganges we had already spotted some likely duplicates, such as Salur and Selur, or Kaliur, Kurula and Karura, but left them all in, as they were located very near each other. Ptolemy's work being inevitably a compilation (Bagrow 1985), the decision to also introduce a separate category for *duplicate* points

came to us naturally. Figures 2-5 below provide a visual representation of our results achieved for Ptolemy's Arabia.
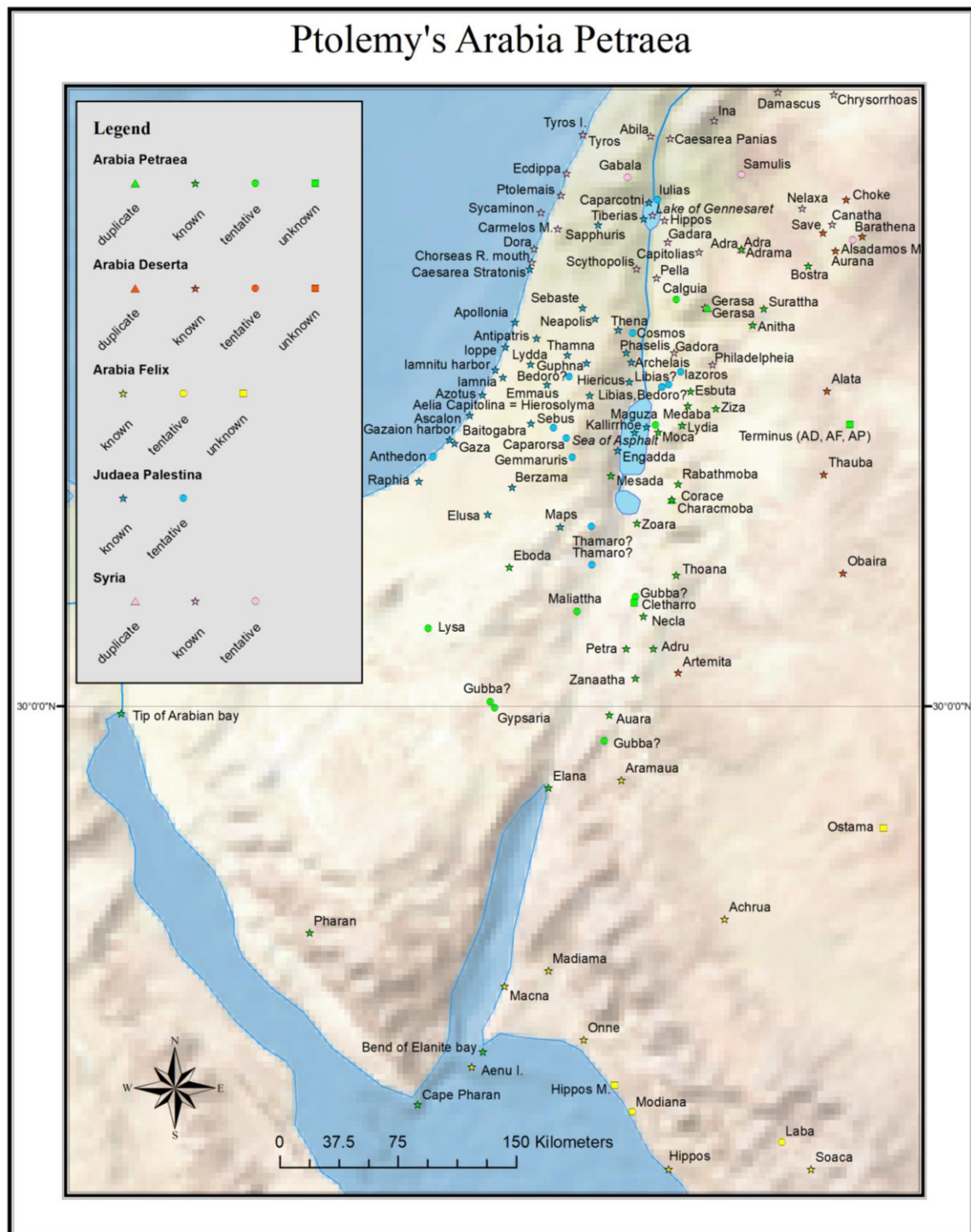


Figure 2. Ptolemy's Arabia Petraea.
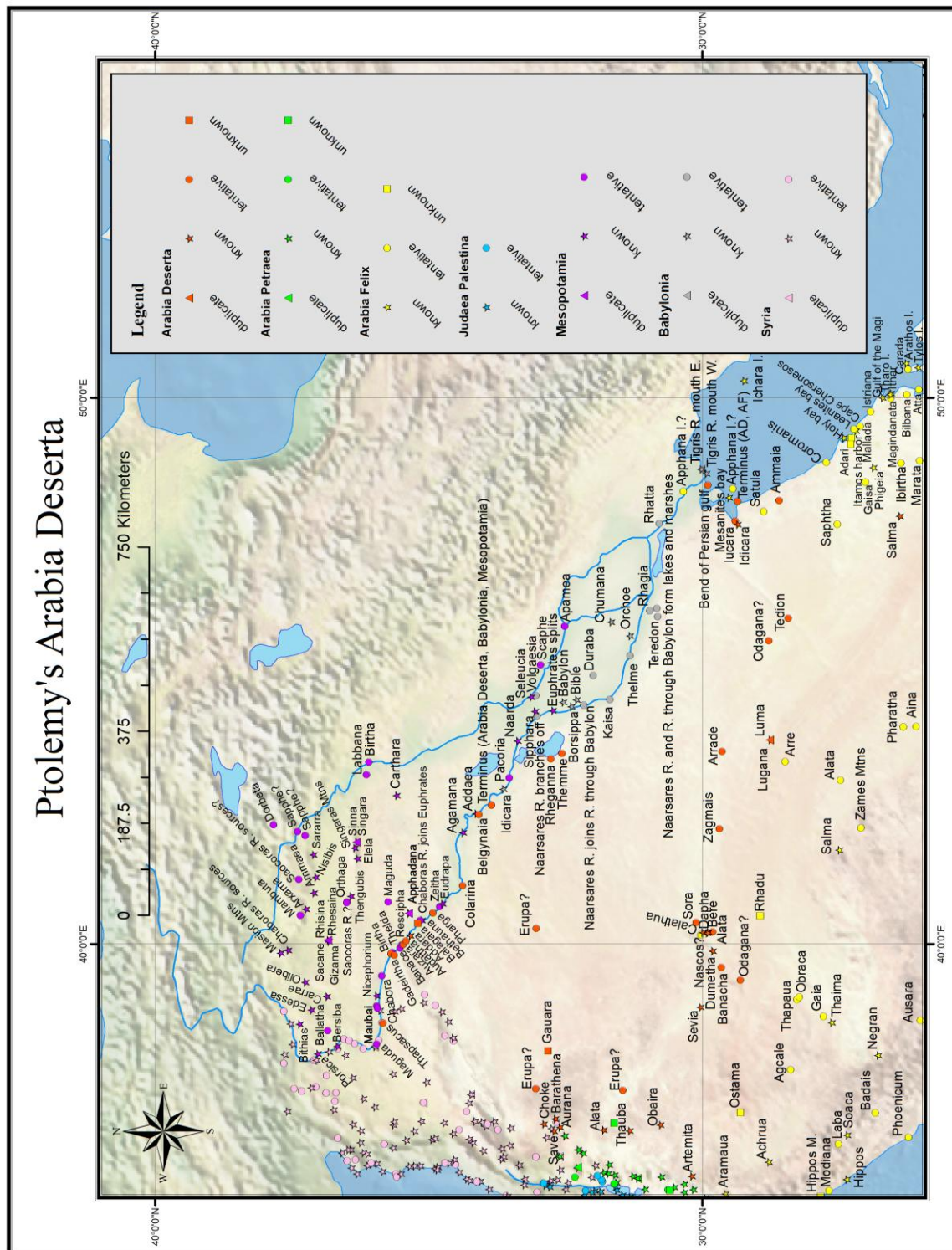
Figure 3. Ptolemy's Arabia Deserta. The toponyms for Syria, Arabia Petraea, and Judaea Palestina are not shown, in order to reduce clutter due to the limitations of the map's scale.
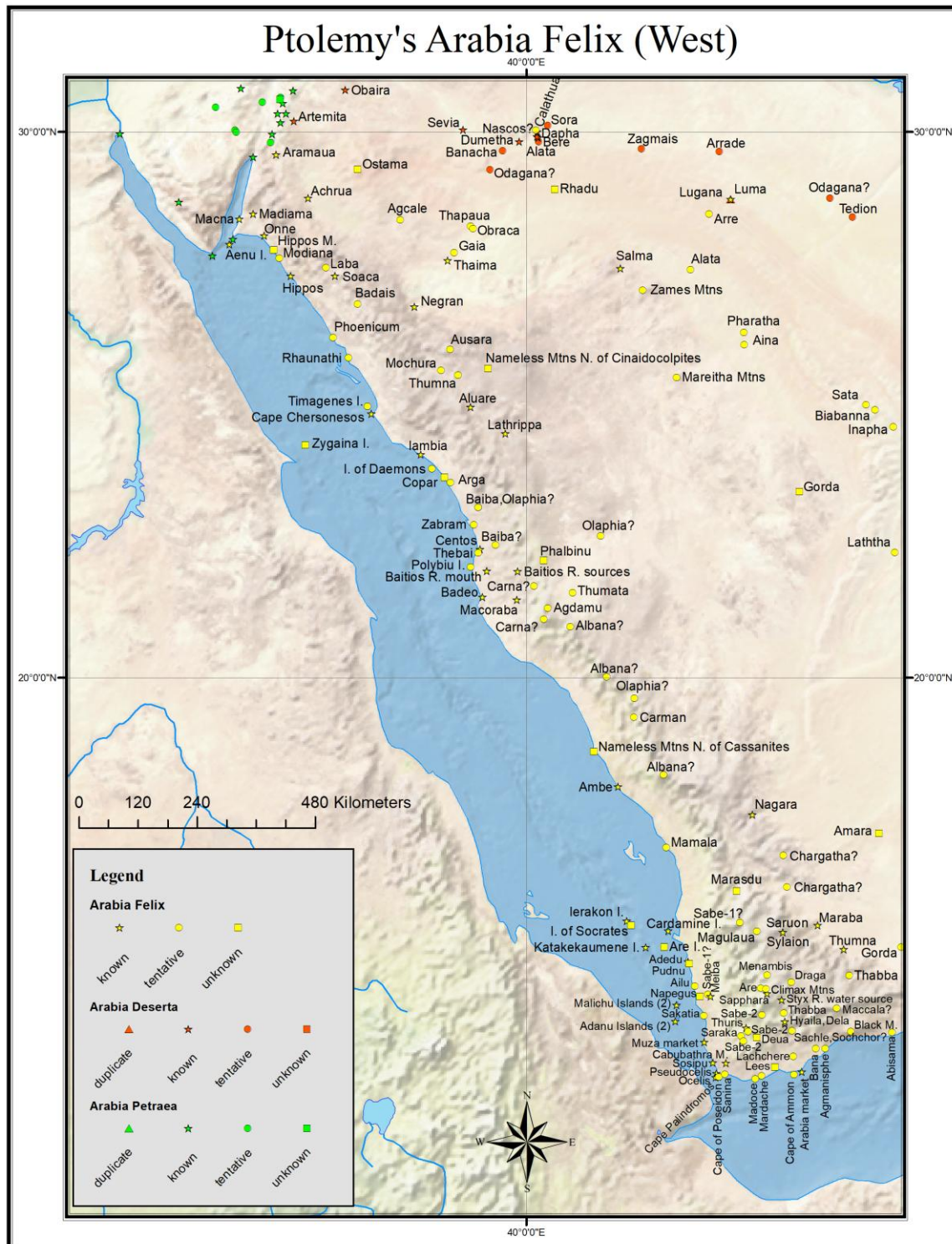
Figure 4. Ptolemy's Arabia Felix (West). The toponyms for Arabia Petraea are not shown. The reader can find them in Fig. 2.
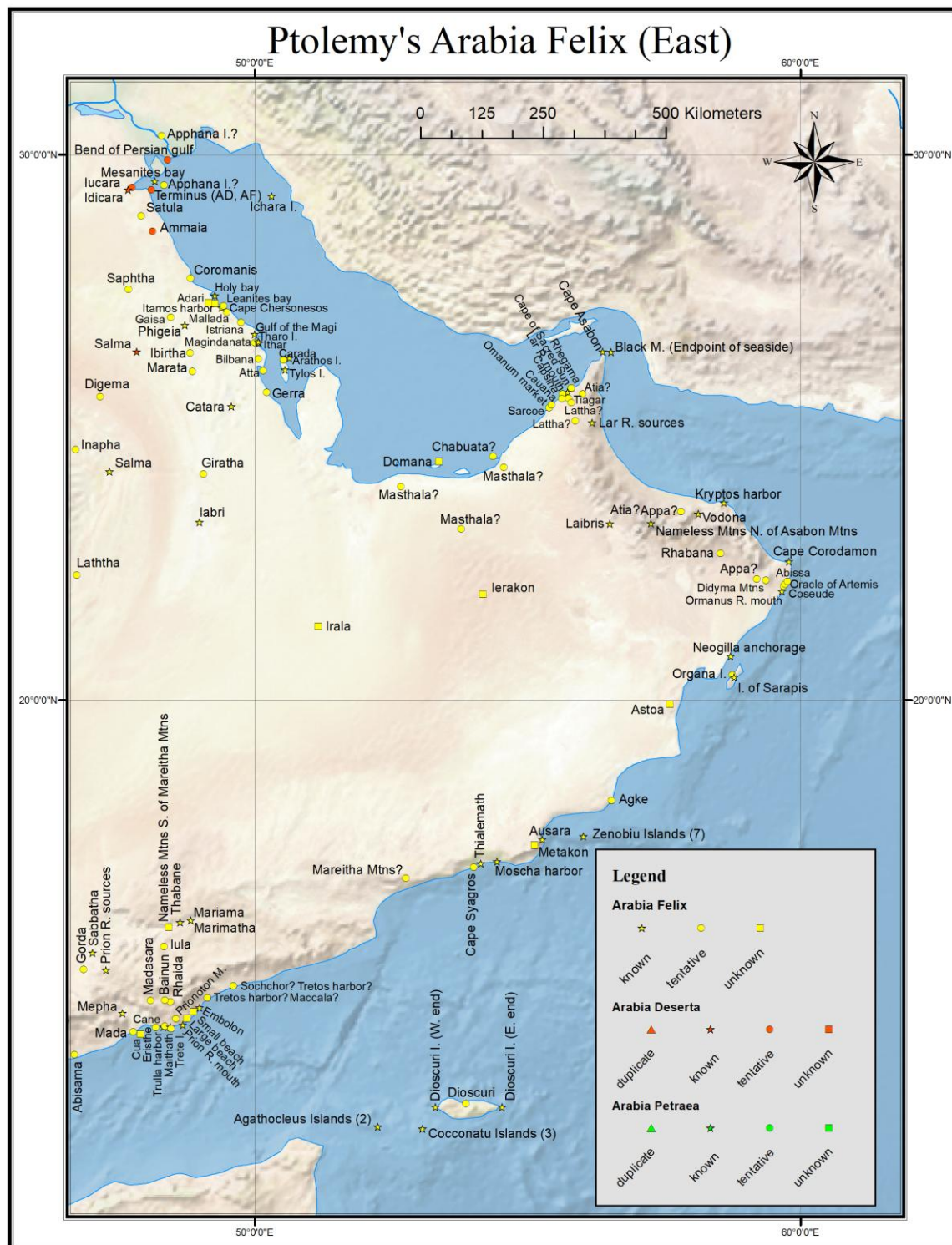
Figure 5. Ptolemy's Arabia Felix (East).

*Identification of Known Points*

It proved relatively easy to positively identify many known points in Arabia Petraea, in addition to the ones already mentioned above.

We corrected a mistake found in (Stückelberger and Grasshoff 2006): Ptolemy's Lydia is not a duplicate of his Lydda (the modern Lod) in Judaea Palestina; rather, it is a place in Arabia Petraea known to Åhlfeldt under the alternative ancient name Libba (the modern Libb). Similarly, Ptolemy's Anitha turned out to be the ancient town also known under the names Hatita, Aditha, and Adeitha (the modern Al Khirbah as Samrā'). However, the difficulty with using the identifications to search for the few remaining unknown points came from the known points apparently forming two overlapping clusters — the "Petra" cluster and the "Bostra" cluster. On a Ptolemaic map, it is fairly easy to see which of the known points "track" with Bostra, including Charakmoba (a duplicate of Corace, the modern Al Karak castle) and Gerasa (the duplicate of Gerasa in Syria, the modern Jarash), and which ones came with Petra (Korake, etc.). Alas, it is hard to tell which of the two clusters the unidentified towns of Gubba and Cletharro belong to. Our triangulation method places Cletharro close to the ancient town and copper mines of Phaino (the modern Feynan, Faynān), but we do not assign much weight to this result. More discussion and examples of point clusters in Ptolemy's *Geography* can be found in (Filatova et al. 2019).

Arabia Deserta was so sparsely populated that Ptolemy assigned several towns located on the fringes of the adjacent provinces to it. For example, Ptolemy restricted Mesopotamia to the area between the Euphrates and Tigris rivers so overly rigorously that many towns located on the southern bank of Euphrates were assigned to Arabia Deserta. One of such Mesopotamian towns formally assigned to Arabia Deserta is Ptolemy's Addara, the modern Deir ez-Zor. On the other side of Mesopotamia, the Assyrian town of Chatracharta (the ruins of Assur located near the modern Ash Sharqāṭ) was placed on the wrong side of the Tigris River. In reality, Assyrians lived on both sides of the Tigris. Likewise, Ptolemy's Eudrapa (Dura Europos) is found in Mesopotamia and therefore placed incorrectly on the northern bank of the Euphrates. Our main achievement in Arabia Deserta is that we have located the cluster of Ptolemaic towns consisting of Save (the modern As Suwayda, also known under the alternative ancient names Soada and Dionysias), Barathena (the modern Busan, also known as Bosana), Choke (the modern Shaqqa), and Aurana (Hobran) on the Syrian border, much closer to the Alsadamos Mountains (Jabal ad Durūz, Tall Ḥawrān) than shown by Ptolemy. We have also corrected the identifications of two towns assigned to Arabia Deserta, yet located on the outskirts of Arabia Petraea. Ptolemy's Artemita corresponds to the modern Ma'an, also known under the alternative ancient name of Ammatha, and not to Qasr Amra, which, in its turn, matches Ptolemy's Alata, the northernmost of the two Arabia Deserta locations so named. Stückelberger and Grasshoff follow Müller (1883-1901) in identifying Ptolemy's Dapha as El-Djob, and that's Al Jawf, the name of a province and formerly of a city called Algwaf in (Johnson 1870) and apparently subsequently swallowed by the nearby city of Sakakah, shown as Schakik in (Johnson 1870).

The rest of the discussion in this subsection will be devoted to identification of known points in Arabia Felix.

In Arabia Felix, we were especially delighted to locate the source of water of the Styx River — "Wasser der Styx-Quelle" of the German translation by Stückelberger and Grasshoff (2006), "the fountain of the Stygian waters" of E. L. Stevenson's English translation (Ptolemy 1991). As the reader might recall, Styx is the mythical river of the Greek Underworld. It flows in the realm of Hades, and gods swear their oaths upon Styx. In Yemen, 32 kilometers away from historical Dhafar (Ẓaffār) that Ptolemy knows as Sapphara, the town of Ḥammām Damt (Damt, Demt) surrounds a spectacular volcano with a lake of hot mineral water in its crater. A tunnel was built in the volcanic rock to let the water out and establish a bathhouse. (The Arabic word *ḥammām*

means 'bath'.) Ḥammām Damt is Yemen's premier mineral water resort featuring several sulphated hot water fountains (Al Kubati et al. 2015).

It was almost equally exciting for us to find Ptolemy's Vodona by following a fascinating story told by a 17th century French traveler Jean-Baptiste Tavernier (1677). We quote the relevant fragments of the story below, complete with our notes.

*During the difference between the King of Persia and the Hollanders, the Emir of Vodana an Arabian Prince offer'd to shew them an easie Road from Mascaté* [Muscat, Ptolemy's Kryptos, i.e. "hidden" harbor] *to Balsara* [the modern Basra, Iraq]... *Had it been yielded to, the way had been from Balsara to Elcatif* [the modern Al Qatif, Saudi Arabia, Ptolemy's Magindanata according to Hamad bin Seray (1997)] *a Sea-Town in Arabia the Happy, where there is a Fishery for Pearls that belongs to the Emir of Elcatif. From Elcatif to Mascalat* [Ptolemy's Masthala, tentatively identified as Mezairaa (Muzayri'), UAE] *another City of Arabia, and the residence of another Emir. From Mascalat to Vodana, a good handsom City seated upon the meeting of two little Rivers that carry Barques to the Sea, and run together by the single name of Moyesur. The Soyl about Vodana produces no Corn, and very little Rice; but it abounds in Fruits... There are extraordinary good Melons and great Store of Grapes, of which the Jews, who inhabit the best part of the City, are permitted to make Wine... From Vodana to Mascatè it is but fifteen Leagues, though by the Maps, which are Erroneous, the way is describ'd to be much longer.*

Slot (1995) mentions that, in a remark aside, Tavernier said that "Amir of Vodena later conquered Muscat." Slot further explains that this "Amir of Vodena" must have been Imam Sultan bin Sayf, who captured Muscat in 1650. Sultan bin Saif was the cousin of Imam Nasir bin Murshid bin Sultan al Ya'Aruba, the ruler of Nizwa, who died there in 1649. He left no sons, so Sultan bin Sayf was selected by the noblemen to succeed him.

Clearly, Nizwa is not Vodona, because Sultan bin Sayf could not be ruling it at the time of the meeting described by Tavernier. The name Nizwa is not similar to Vodona. Moreover, Nizwa is more than 130 kilometers away from Muscat by a straight line. This distance far exceeds 15 leagues (~72 km). Having previously identified Ptolemy's Lar River as Wadi Lamḥah, we were not surprised to learn that the Ptolemaic map was wrong here. At first, the wadi proceeds upstream in the southern direction from the Gulf for approximately 50 km, then turns east, toward its source, Wadi Sifūnī.

However, on the road from Nizwa to Muscat, past a known archaeological pre-Islamic site at Samail, we find a place where two wadis meet to form Wādī Manşaḥ (Tavernier's *Moyesur*). These two streams are named Wādī Bidbid and Wādī Nafʿah after the nearby towns. Of those two towns, Vodona must be Bidbid, known for an old fort. The town's name is likely derived from the Arabic word *nabidh* that means 'wine', cf. Hebrew *nofet*, 'honey'. The original name would have been Nabidh-Nabidh, offering some similarity to Vodona.

The route proposed by the Emir would lead from the mouth of Wādī Buḥayyiş or Wādī Samā'il up the river to Bidbid, then across the mountains to Nizwa, then, most likely to Ibri (literally, the Hebrew town, Ptolemy's Laibris), then to Mascalat (Ptolemy's Masthala), then to Elcatif (Magindanata). On the Ptolemaic map, the part of this route from Vodona to Magindanata bypasses the Lar River, which happens to be correct. But the relative positioning of Vodona and the "nearby" Nagara — the modern city of Najran, Yemen, actually located 1,600 kilometeres away from Bidbid — is terribly erroneous, so the vast Rub' al Khali sand desert is eliminated. If this mistake did not happen, we would likely see the name Arabia Deserta elsewhere on the map.

Following the shore south from the mouth of Ormanus (Batha) River, we spotted Khawr Barr al Ḥikmān, a convenient harbor located between a town called An Nuqdah and a matching cape,

Ra's an Nuqdah. We identify this harbor as Ptolemy's *Neogilla anchorage* and further suggest that the Ptolemaic name is a likely corruption of *Neogidda*, ΛΛ written mistakenly instead of ΔΔ. D'Anville and Horsley (1791) reported that the city of Badeo had retained the name of Badea in its maritime position. A "point of land" which formed the southern boundary of the creek (Wādī Fāṭimah), at the mouth of which the modern port of Jeddah is situated, was still called Ras Bad back then. The old downtown of Jeddah is presently known as Al-Balad, so we can safely identify Ptolemy's Badeo as Jeddah. This identification is consistent with that of the Baitios River mouth situated just north from Badeo, and with those of Mecca (Macoraba) and Medina (Lathrippa).

Numerous certain identifications of points marking the route along the southern coast of Arabia, from Muza market (the modern Mocha) to Ausara (Hasik), Zenobiu Islands (Khuriya Muriya), and the Island of Sarapis (Masirah) rely upon the valuable information found in the *Periplus of the Erythraean Sea* (Schoff 1912). Here's an illuminating fragment of the periplus, with our brief notes.

*Beyond the harbor of Moscha* [Sumhuram, Khawr Rawrī] *for about fifteen hundred stadia as far as Asich* [modern Hasik, Ptolemy's Ausara]*, a mountain range runs along the shore; at the end of which, in a row, lie seven islands, called Zenobian* [modern Khuriya Muriya]*... Sailing along this coast well out at sea for two thousand stadia from the Zenobian Islands, there meets you an island called Sarapis* [Masirah]*, about one hundred and twenty stadia from the mainland. It is about two hundred stadia wide and six hundred long, inhabited by three settlements of Fish-Eaters, a villainous lot, who use the Arabian language and wear girdles of palm-leaves. The island produces considerable tortoise-shell of fine quality, and small sailboats and cargo-ships are sent there regularly from Cana* [Qana', Ḥiṣn al Ghurāb]*.*

Taking one (Ptolemaic or Attic) stade to be approximately 185 m long, it is straightforward to make sure that the size and location of Masirah Island are specified with good precision here. To give just one more example where the periplus helps, Ptolemy's Pseudocelis is confidently identified as Khawr Shūrī, the only harbor that can be mistaken for Khawr Ghurayrah, the harbor of Ocelis (Bi'r al Ḥālī) that, in its turn, can be easily identified from its description in the periplus. The Arabic word *bi'r* means 'well', and we can speculate that, unlike Ocelis, Pseudocelis did not provide fresh water.

The Greek name of Katakekaumene Island means 'burnt', 'burned down', so this must be a volcanic island. The modern name of one of such islands, Jebel at Tair, means 'Bird Mountain' in Arabic, so it is identified as Ptolemy's Ierakon Island, the 'island of hawks'. (Stückelberger and Grasshoff mistakenly translate "der Adler", i.e. 'of eagles'.) Another notable volcanic island, Jabal Zubayr, is then identified as Ptolemy's Katakekaumene Island by its relative positioning.

Unfortunately, the size of this paper does not allow us to discuss all identifications of the known points in detail. The tables of modern coordinates for known locations in Ptolemy's Arabia Petraea, Arabia Deserta and Arabia Felix are provided in Appendix A at the end of the paper.

*Identification of Duplicates*

In addition to the aforementioned duplicate pairs (Corace-Charakmoba and two instances of Gerasa), Ptolemy's Adra (the modern Daraa) from Arabia Petraea has two duplicates in Syria — Adra and Adrama.

In Arabia Deserta, we believe that Luma is a duplicate of Lugana from Arabia Felix, the modern Linah in Saudi Arabia. Johnson (1870) shows this place as Lyneh. The town of Gauara is a possible duplicate of Koara or Goaria in Syria (ancient Sauara, modern Aş Şawarah al Kubrá). Idicara

is a likely duplicate of Iucara (the modern Jahra), or, perhaps, even of Idicara in Babylonia, the modern Hīt, a town located near the point where Wadi 'Īdī enters the Euphrates. Gadeirtha is a possible duplicate of Addaia in Mesopotamia, the modern Haditha. Contrary to the identification proposed by Stückelberger and Grasshoff following Müller (1883-1901), Gadeirtha is definitely not Ğedeide, the modern Jedeide (Jdaide, Jdeideh) in Lebanon, which is too far away.

Ptolemy lists three places in Arabia named Salma. The one assigned to Arabia Deserta is not Hail, in another contradiction to Stückelberger and Grasshoff. Rather, it's the modern Sihmah, the town called Salema by Bonne (1771) and Selimah by Johnson (1870). The Salma located near Hail, Al Samra (next to a mountain called Jabal Samrā') is, actually, Salma-2 from Arabia Felix. Salma-3 corresponds to the ruins near Al Yamamah, 5 km away from the modern As Salamīyah. We believe that these three places are not duplicates.

In Arabia Felix, Mariama is a duplicate of Marimatha, the modern Maryama. Saruon is a duplicate of Sylaion, the modern As Sarw. Sochchor is placed inland, where it may be a duplicate of Sachle, the modern As Safra'. Alternatively, it may correspond to the coastal city of Ash Shiḥr. Dela is a duplicate of Hyaila, the modern town of Ad Dali, also known as Dhalie, m-Dakhla, and m-Dakhayla. One of the towns named Gorda is a possible duplicate of Giratha (the modern Haradh). Carna is a possible duplicate of Carman: the word *qarn* means 'horn' in Arabic, so we should expect to encounter a place named Carna in the mountainous area. Atia is a possible duplicate of Appa. Marasdu and Amara are possible duplicates of Maraba (the modern Marib).

Laththa is a likely duplicate of Lattha, which is tentatively identified as the modern archaeological fort of Maleha, a place also called Al Malaiha, Meliha, Maliha, Mlayḥa, Mulayḫah, Mileiha, and Mleiha. Alternatively, Lattha may correspond to Lamḥah, a dune adjacent to Wadi Lamḥah, Ptolemy's Lar River, while Laththa may represent the oasis of Layla.

Ptolemy's Atta is a likely duplicate of his Magindanata, tentatively the modern Al Qatif. Hamad bin Seray (1997) plausibly derives the name Magindanata from the Aramaic *mdinta Hatta*, an equivalent of the Arabic Madinat al-Khatt. He explains that Qatif used to be called al-Hatt, or Al-Khatt. A cape named Ra's al Khaththāq currently exists nearby.

Thabba may be a duplicate of Sabbatha, which corresponds to one of the two Yemeni towns named Shabwah, specifically, to the ancient capital of Yemen located at lat = 15.3684, lon = 47.0228. Talbert and Åhlfeldt mistakenly use coordinates of the other Shabwah: lat = 14.5440, lon = 45.9097. It is not inconceivable that Thabba represents this other Shabwah.

Ptolemy lists two locations in Arabia Felix named Sabe. Yemen, the land of ancient Sabaeans, offers many tempting choices for tentative identification, which will be discussed in the next section.

In Mesopotamia, Ptolemy's Rhesaina and Sacane are both commonly believed to be duplicates of his Rhisina, the ruins of which are located on a hill called Tell Fecheriye, next to a modern city known as Ra's al 'Ayn and Sari Kani. To conclude the subsection, let us give an example where the names of the duplicates do not look or sound alike. Ptolemy's *Aspis colonia* and *Clypea colonia* in the province of Africa are actually one and the same place. Aspis means 'shield' in Greek, and Clypea (or Clupea) means the same thing in Latin. This error in Ptolemy's *Geography* was discovered a long time ago (Sale et al. 1747-1768). We wonder if Ptolemy actually knew Latin, and if he did, whether he knew it well.

*Tentative Identification*

In Arabia Petraea, we tentatively identify Ptolemy's Maliattha as the present day ruins of Moaa, also called Horvat (=Khirbet=Kharabat, i.e. 'ruins') Mo'a, Moyat Awad, and Moyat 'Awad. Talbert and Åhlfeldt tentatively idenify these ruins as Ptolemy's Calguia. We tentatively identify Calguia as Ajloun. Following Talbert and Åhlfeldt, we tentatively identify Ptolemy's Lysa as the ruins called Kharabat Lussan and located near Wadi Lussan. Likewise, we take their suggestion and tentatively identify Ptolemy's Gypsaria as the ruins of an ancient fort near Al Kuntillah. Following Stückelberger and Grasshoff, we tentatively identify Maguza as the modern Ḥammāmāt Mā'īn, a resort located near the slopes called Ad Dabbūsah.

Stückelberger and Grasshoff identify Ptolemy's Gubba as "Wadi el-Gubey" following Kiepert (1856), who illustrated (Robinson and Smith 1841). The modern names of this stream are Wadi Abu Guweia, Wadi Abu Juway', and Wadi al Ghubah. The ruins of interest would be located in the vicinity of the modern Themileh. However, it is also possible that Ptolemy's Gubba is the ancient Phaino (the modern Feynan, Faynān) located near Wadi Ghuwayr. A third likely possibility is that Gubba is the old fort of Quweira.

In Arabia Deserta, we tentatively identified the legendary Thapsacus as Ath Thawrah, formerly Al Tabqah, where a modern dam was built to create the Lake Assad reservoir. Thapsacus was a historically famous point for crossing the Euphrates River, but we don't actually know where the city once stood. The word Birtha means 'fortress' in Syrian, so we tentatively identified Ptolemy's Birtha with the ruins of the ancient fortress of Zenobia located near the present day Halabiyah. Many other tentative identifications were made. For example, Ptolemy's Rheganna was tentatively identified as the present day Ar Rahaliyah known for remains of early Christian churches. We placed the identification of Themme as 'Ayn Tamr proposed by Stückelberger and Grasshoff into the tentative category. Three different possible locations for Ptolemy's Erupa were found: Rutba, Ruḥbah, and Ar Rukbān. Only the second of them, under the old name Er-Ruhbe, was given by Stückelberger and Grasshoff following Müller. We tentatively identified the second Alata with the al-Rajajeel ruins located near a ravine named al 'Uqdah.

The tentative identifications proposed for the places that Ptolemy mentions in Arabia Felix are too numerous to list here. It was especially difficult to locate Ptolemy's Cape Syagros. Ptolemy moved it relatively to the Moscha harbor, contrary to the opinion of Marinus of Tyre, his predecessor and most valuable source. West to east, we considered Ra's Fartak, Ra's Sajir, Ra's Raysūt, the cape next to Jabal Qinqarī, and Ra's Ṣawqirah. The *Periplus of the Erythraean Sea* (Schoff 1912) relays the following.

*Beyond Cana, the land receding greatly, there follows a very deep bay stretching a great way across, which is called Sachalites... On this bay there is a very great promontory facing the east, called Syagrus; on which is a fort for the defence of the country, and a harbor and storehouse for the frankincense that is collected... Immediately beyond Syagrus the bay of Omana cuts deep into the coast-line, the width of it being six hundred stadia; and beyond this there are mountains, high and rocky and steep, inhabited by cave-dwellers for five hundred stadia more; and beyond this is a port established for receiving the Sachalitic frankincense; the harbor is called Moscha, and ships from Cana call there regularly...*

We share the viewpoint of Beeston (1981), who argued in favor of Ra's Raysūt being Cape Syagros, because it faces east, allows a fort to be built on it, and shields a convenient harbor of Raysūt.

Ptolemy's inland city of Maccala was often identified to be the modern port of Al Mukallah. While this remains a possibility, we tentatively identify Maccala as the modern Mukayris. Al Mukallah or the nearby Ash Shihr might be Ptolemy's Tretos harbor. However, it is difficult to imagine Tretos harbor not being near Trete Island, tentatively the modern Barrāqah Island.

We tentatively identify Ptolemy's Thebai as the modern Thuwal, Ailu as Al Jāḥ al A'lá, Mada as Al Mijda, Abissa as Ar Ru'ays (it could be Arissa, ρ instead of β), Rhegama as the known archaeological site called Al Jazira Al Hamra, Carada as Karranah (another known archaeological site), Gerra as Al 'Uqayr (this is the dominant version in the literature), Bilbana as Bi'r Abū 'Idbūlah, a well situated at or near the location suggested by Spruner (1865), Pharatha as Buraydah, Gaia as Ghayl al-Waggag (near Tayma), Ibirtha as Ābār 'Irj, Sata as Sadus, an old village on Wadi Hanifa, Inapha as Diriyah, also on Wadi Hanifa, Atia as Afi or Khatt, Appa as Afi or Al Kamil Wal Wafi, Thumata as Thamūdah, Iula as Al Huwaylah, Lachchere as Laḥij, etc.

We tentatively identify Ptolemy's Cauana as ed-Dur, a famous archaeological site located near the modern Umm Al Quwain, alternatively spelled Umm al Qaywayn. The name ed-Dur merely means 'houses', reflecting the present state of the ruins. Some sources suggested that ed-Dur might be the mysterious Ommana. We tentatively identify Ptolemy's Omanum market with the modern Ajman, once a small old fishing village. Hopefully, the earlier discourse about Ptolemy's Vodona prepared the reader to take our version seriously. Our suggestion is reasonably consistent with the *Periplus of the Erythraean Sea*, which states:

*Sailing through the mouth of the* [Persian] *Gulf, after a six-days' course there is another market-town of Persia called Ommana.*

Following the old sources, we tentatively identify Ptolemy's Carman as the ruins of Al Manzil, formerly known as Qarn-al-Manazil (lat=19.2729, lon=41.9650). This place was hard to find!

It is unclear if Ptolemy's Baiba is the historical Al Abwa, or Baḥwil, a village located near Ḍabyah on the comparably historical Mecca-Medina road.

Ptolemy's Sabe-1 in Yemen is either Zabid, or Shibam (lat=15.5092, lon=43.9032), which should not be confused with another Shibam, Ptolemy's Thabane (lat=15.9264, lon=48.6260), also known as "Manhattan of the Desert". Ptolemy's Sabe-2 could be Jabal Şabir, As Sawā'il (Talbert 2000), or Ash Shi'bah.

The tables of modern coordinates for tentatively identified locations in Ptolemy's Arabia Petraea, Arabia Deserta and Arabia Felix are provided in Appendix B at the end of the article.

**Precision Analysis**

In our previous paper (Abshire et al. 2016), we predicted that the precision of our methods for numerical prediction in other regions may surpass the one achieved in India. The prediction was based upon understanding that India was definitely not the region that Ptolemy knew best, given how distorted it was, and in anticipation that the percentage of known points was likely to be higher in many other regions. The new results allowed us to compare the predictive performances of triangulation and flocking models before and after the Bayesian correction for India before the Ganges, Taprobane, Arabia Petraea, Arabia Deserta, Arabia Felix, Judaea Palestina, and Syria. The error histograms for the leave-one-out known point predictive analysis using the modified flocking model with Bayesian adjustment for Arabia Petraea and India before the Ganges are contrasted in Figure 6. The leave-one-out analysis is a common statistical technique, where we pretend that we do not know the coordinates for one of the known points, predict the coordinates using one of our methods, and compute error as the distance between the actual and predicted

points. The histograms illustrate how the errors are distributed for complete sets of known points.
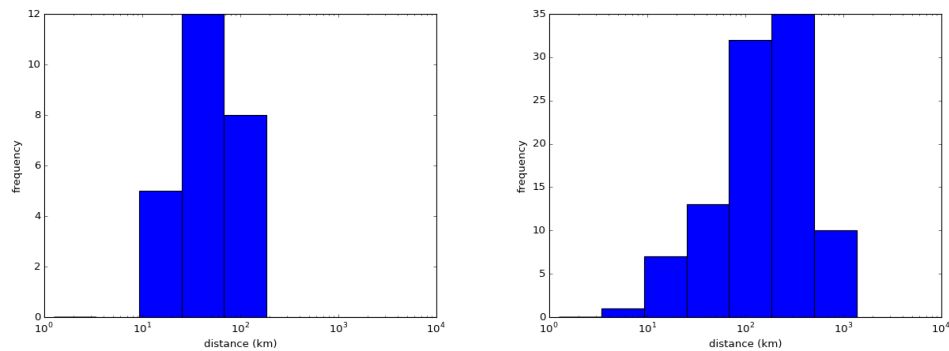


Figure 6. Error histograms for Arabia Petraea (left) and India before the Ganges (right) for the modified flocking model with Bayesian adjustment.

Clearly, we are better off in Arabia Petraea.

## Conclusions and Future Work

We modified and adjusted our computational methods for numerical analysis of historical data from Ptolemy's *Geography* and extended their application to Arabia. This new achievement allowed us to perform the additional model validation and region-to-region comparison of predictive performances of our two models (triangulation and flocking) before and after the Bayesian adjustment. Our results represent a novel research contribution to understanding of our historical cartographic heritage by improving our ability to explore Ptolemy's *oikouménē*, the "known world" of the ancients, using familiar and available GIS tools, such as Esri ArcGIS, QGIS, and Google Earth.

In the future, we plan to apply our methods to other regions from Ptolemy's *Geography*. We also intend to modify the techniques to enable tentative identification verification. Yet another natural extension is to improve our reconstruction of Ptolemy's Arabia, where a lot of uncertainty remains as to locations of many ancient objects. Ideally, we would love to see field archaeologists travel to a suggested location and discover a lost ancient city mentioned by Ptolemy.

## Acknowledgments

## References

Abshire, C., D. A. Gusev, I. Papapanagiotou, and S.K. Stafeyev (2016). A Mathematical Method for Visualizing Ptolemy's India in Modern GIS Tools. *e-Perimetron* 11(1): 13–34.

Åhlfeldt, J. (2015). *Digital Atlas of the Roman Empire*. In digital form, http://dare.ht.lu.se/

Al Kubati, M., M. A. Mattash, M. F. Alnethary, A. Minissale and O. Vaselli (2015). Geothermal Exploration and Geothermometric Characteristics of Western Area in Yemen. Proceedings of the

*World Geothermal Congress 2015*. Melburn, Australia: The International Geothermal Association.

Almutairi, M. (2011). *Archaeology of Kuwait*. Ph.D. thesis. Cardiff University: School of History and Archaeology.

Bagrow, L. (1985). *History of Cartography, 2ⁿᵈ ed.*, R. A. Skelton (ed.). Chicago: Precedent Books.

Beech, M. J. (2004). *In the Land of the Ichtyophagi*. Oxford: Archaeopress.

Beeston, A. F. L. (1981). Review of Huntingford 1980. *BSOAS* 44: 353−358.

Berggren J. and A. Jones (2000). *Ptolemy's Geography: An annotated translation of the theoretical chapters*. Princeton, NJ: Princeton University Press.

Bonne, R. (1771). *Carte de l'Arabie*. Paris: R. Bonne.

Bowersock, G. W. (1971). A Report on Arabia Provincia. *The Journal of Roman Studies* 61: 219−242.

Brice, W. C. (1974). The Construction of Ptolemy's Map of South Arabia. *Proceedings of the Seminar for Arabian Studies* 4: 5−9. Cambridge: The Middle East Center.

Colton, J. H. (1855). *Colton's Persia, Arabia, etc*. New York, NY: J. H. Colton.

D'Anville J. B. B. and J. Horsley (1791). *Compendium of Ancient Geography, Vol. 2*. London: R. Faulder.

Diller, A. (1935). Review of Stevenson's translation. *Isis* 22 (2): 533−539. In digital form, http://penelope.uchicago.edu/Thayer/E/Journals/ISIS/22/2/reviews/Stevensons_Ptolemy*.html

Dougherty, R. P. (1930). A Babylonian City in Arabia. *American Journal of Archaeology* 34 (3): 296−312.

Filatova L. M., D. A. Gusev, S. K. Stafeyev (2019). Iterative reconstruction of Ptolemy's West Africa Using Modern GIS Analysis. Proceedings of the 14ᵗʰ ICA Conference on *Digital Approaches to Cartographic Heritage*. Thessaloniki, Greece: The International Cartographic Association.

Forster, C. (1844). *The Historical Geography of Arabia*, in 2 Vols. London: Duncan and Malcolm.

Gibson, D. (2013). Suggested Solutions for Issues Concerning The Location of Mecca in Ptolemy's Geography. *Nabataea*. In digital form, https://www.researchgate.net/publication/256702804_Suggested_Solutions_for_Issues_Concerning_The_Location_of_Mecca_in_Ptolemy's_Geography

Görsch, N. (2017). Ptolemy's Geography and the Tabulae modernae — A Comparison of Maps Using the Example of the Arabian Peninsula. Proceedings of the *22nd International Conference on Cultural Heritage and New Technologies*. Vienna, Austria: Eurographics Symposium and Graphics Cultural Heritage.

Graßhoff, G., F. Mittenhuber, and E. Rinner. (2017) *Of paths and places: the origin of Ptolemy's Geography*. Archive for History of Exact Sciences 71 (6): 483−508.

Groom, N. (1986). Eastern Arabia in Ptolemy's Map. Proceedings of the 19ᵗʰ Seminar for *Arabian Studies* 16: 65−75. Oxford: Archaeopress.

Haerinck, E. (2012). The Temple at Ed-Dur (Emirate of Umm al-Qaiwain) and Pre-Islamic Cult in Southeastern Arabia. Proceedings of the 2ⁿᵈ International Conference on the *Archaeology of the*

*United Arab Emirates*, D. T. Potts and P. Hellyer (eds.): 162−171. Abu Dhabi: Motivate Publishing.

Hamad bin Seray (1997). The Arabian Gulf in Syriac Sources. In G. R. Smith, B. R. Pridham (eds.), *New Arabian Studies, Vol. 4*. Exeter: University of Exeter Press, 205−232.

Izaksen, L. (2012). Ptolemy's Geography and the Birth of GIS. Proceedings of *Digital Humanities 2012*. Hamburg: Alliance of Digital Humanities Organizations. In digital form, http://www.dh2012.uni-hamburg.de/conference/programme/abstracts/ptolemys-geography-and-the-birth-of-gis.1.html

Johnson, A. J. (1870). *Johnson's Persia, Arabia, Beloochistan and Afghanistan*. New York, NY: A. J. Johnson.

Kiepert, H. (1856). *Map of the Peninsula of Mount Sinai and Arabia Petraea*. Boston, MA: Crocker & Brewster.

Manoledakis M., E. Livieratos (2006). On the digital placement of Aegae, the first capital of ancient Macedonia, according to Ptolemy's *Geographia*. *e-Perimetron* 2 (1): 31−41.

McCrindle, J. W. (1927). *Ancient India as described by Ptolemy*. New Delhi: Munshiram Manoharlal Publishers Pvt. Ltd.

Müller, K. (1883-1901). *Klaudiou Ptolemaiou Geographikê hyphêgêsis: Claudii Ptolemaei Geographia*, 2 vols. Paris: Firmin-Didot.

Munro-Hay, S. C. H. (1991). The Coinage of Shabwa (Hadhramawt), and Other Ancient South Arabian Coinage in the National Museum, Aden. *Syria* 68 (1-4): 393−418.

Ptolemy, C. (1991). *Claudius Ptolemy, The Geography*, Translated and edited by E. L. Stevenson. New York, NY: Dover Publications, Inc.

Potts, D. (1984). Northeastern Arabia, from the Seleucids to the Earliest Caliphs. *Expedition* 26 (3): 21−30.

Potts, D. (2001). Before the Emirates: An Archaeological and Historical Account of Developments in the Region c. 5000 B.C. to 676 A.D.  In Al Abed-Hellyer (eds.), *United Arab Emirates: A new perspective*. United Kingdom: Trident Press, 28−69.

Robinson E. and E. Smith (1841). *Biblical Researches in Palestine, Mount Sinai and Arabia Petraea: A Journal of Travels in the Year 1838, Vol. 1*. London: John Murray.

Sale, G., G. Psalmanazar, A. Bower, G. Shelvocke, J. Campbell and J. Swinton (1747-1768). *An Universal History, from the Earliest Account of Time to the Present*. London: E. Symon.

Schoff, W. H. (1912). *Periplus of the Erythraean Sea: Travel and Trade in the Indian Ocean by a Merchant of the First Century*, Translated from the Greek and Annotated. New York, NY: Longmans, Green, and Co.

Slot, B. J. (1995). *The Arabs of the Gulf, 1602–1784*. Leidschendam: B. J. Slot.

Sprenger, A. (1875). *Die alte Geographie Arabiens als Grundlage der Entwicklungsgeschichte des Semitismus*. Bern, Switzerland: Commissionsverlag von Huber & Comp.

Spruner, K. (1865). *Atlas Antiquus*, H. T. Menke (ed.). Gotha, Germany: Justus Perthes.

Stückelberger A. and G. Grasshoff (2006). *Klaudios Ptolemaios: Handbuch der Geographie, Griechisch-Deutsch*. Basel: Schwabe Verlag.

Talbert, R. J. A. (ed.) (2000). *Barrington Atlas of the Greek and Roman World*. Princeton, NJ: Princeton University Press.

Tavernier, J.-B. (1677). *The Six Voyages of John Baptista Tavernier, Baron of Aubonne through Turky, into Persia and the East-Indies, for the Space of Forty Years*. London: William Godbid.

Tsorlini, A. (2011). *Claudius Ptolemy "Geōgrafikē Yfēgēsis" (Geographia): digital analysis, evalua-tion, processing and mapping the coordinates of Greece, the Mediterranean and the Black Sea, based on 4 manuscripts and 15 printed editions, from Vaticanus Urbinas Gr. 82 (13th cent.) until today : the new Catalogue "GeoPtolemy- θ"*. Ph.D. thesis. Aristotle University of Thessaloniki: School of Rural and Surveying Engineering. In digital form, http://digital.lib.auth.gr/record/128272

## Appendix A. Tables of Known Points

*Table 1. Modern coordinates for known locations in Arabia Petraea (Book 5 Chapter 17).*

| Ptolemy ID | Ptolemy Name | Modern Name | Ptol. Lat. | Ptol. Lon. | Mod. Lat. | Mod. Lon. |
|---|---|---|---|---|---|---|
| 5.17.01.05 | Tip of Arabian bay | Suez bay | 29.83 | 63.50 | 29.9588 | 32.5588 |
| 5.17.01.08 | Cape Pharan | Ras Muhammad | 28.50 | 65.00 | 27.7242 | 34.2510 |
| 5.17.01.10 | Bend of Elanite bay | Ras Gasabah | 29.00 | 66.00 | 28.0242 | 34.6243 |
| 5.17.01.11 | Pharan | Feiran | 28.67 | 65.00 | 28.7051 | 33.6340 |
| 5.17.01.12 | Elana | Ailan | 29.25 | 65.67 | 29.5337 | 34.9989 |
| 5.17.04.01 | Eboda | Avdat | 30.50 | 65.25 | 30.7944 | 34.7735 |
| 5.17.05.01 | Petra | Petra | 30.33 | 66.75 | 30.3291 | 35.4425 |
| 5.17.05.03 | Auara | Humayma | 29.67 | 66.17 | 29.9499 | 35.3458 |
| 5.17.05.04 | Zanaatha | Aş Şadaqah | 29.83 | 66.75 | 30.1611 | 35.4949 |
| 5.17.05.05 | Adru | Ayn Udhruḥ | 29.92 | 67.00 | 30.3292 | 35.5957 |
| 5.17.05.06 | Zoara | Ghour al Safi | 30.50 | 67.33 | 31.0468 | 35.5022 |
| 5.17.05.07 | Thoana | Wadi at Tawānah | 30.50 | 67.50 | 30.7501 | 35.7268 |
| 5.17.05.08 | Necla | Nijil | 30.25 | 67.50 | 30.5150 | 35.5392 |
| 5.17.05.10 | Moca | Mukawir | 30.17 | 67.83 | 31.5673 | 35.6243 |
| 5.17.06.01 | Esbuta | Tell Hesban | 31.00 | 68.92 | 31.8006 | 35.8090 |
| 5.17.06.02 | Ziza | Al Jiza | 31.00 | 68.75 | 31.7031 | 35.9523 |
| 5.17.06.04 | Medaba | Madaba | 30.75 | 68.50 | 31.7191 | 35.7941 |
| 5.17.06.05 | Lydia | Libb | 30.67 | 69.00 | 31.6058 | 35.7611 |
| 5.17.06.06 | Rabathmoba | Ar Rabbah | 30.50 | 68.50 | 31.2705 | 35.7376 |
| 5.17.06.07 | Anitha | Al Khirbah as Samrā' | 31.25 | 68.67 | 32.1805 | 36.1634 |
| 5.17.07.01 | Surattha | Al Thugra | 31.17 | 69.25 | 32.2723 | 36.2273 |
| 5.17.07.02 | Bostra Legio III Cyrenaica | Buşrá ash Shām | 31.50 | 69.75 | 32.5176 | 36.4816 |
| 5.17.07.03 | Mesada | Masada | 31.50 | 69.33 | 31.3187 | 35.3542 |
| 5.17.07.04 | Adra | Daraa | 31.33 | 69.67 | 32.6126 | 36.0994 |
| 5.17.07.05 | Corace | Al Karak castle | 30.08 | 68.00 | 31.1809 | 35.7017 |

*Table 2. Modern coordinates for known locations in Arabia Deserta (Book 5 Chapter 19).*

| Ptolemy ID | Ptolemy Name | Modern Name | Ptol. Lat. | Ptol. Lon. | Mod. Lat. | Mod. Lon. |
|---|---|---|---|---|---|---|
| 5.19.03.07 | Addara | Deir ez-Zor | 34.17 | 74.33 | 35.3357 | 40.1449 |
| 5.19.04.04 | Iucara | Jahra | 29.25 | 79.00 | 29.3514 | 47.6760 |
| 5.19.05.01 | Barathena | Busan | 33.00 | 73.33 | 32.6873 | 36.7893 |
| 5.19.05.02 | Save | As Suwayda | 33.00 | 73.00 | 32.7079 | 36.5653 |
| 5.19.05.03 | Choke | Shaqqa | 32.50 | 72.50 | 32.8968 | 36.6975 |
| 5.19.05.05 | Aurana | Hobran | 32.67 | 73.25 | 32.6054 | 36.6370 |
| 5.19.05.07 | Alata | Qasr Amra | 32.00 | 72.50 | 31.8030 | 36.5886 |
| 5.19.06.03 | Thauba | Qasr Tuba | 30.50 | 72.75 | 31.3260 | 36.5708 |
| 5.19.06.04 | Sevia | Subayhah | 30.50 | 73.50 | 30.0323 | 38.8356 |

| 5.19.06.05 | Dapha | Sakakah | 30.50 | 74.25 | 29.9930 | 40.2019 |
| 5.19.07.01 | Obaira | Bā'ir | 30.75 | 71.00 | 30.7615 | 36.6793 |
| 5.19.07.02 | Artemita | Ma'an (Ammatha) | 30.17 | 72.25 | 30.1915 | 35.7386 |
| 5.19.07.04 | Dumetha | Dumat Al-Jandal | 29.67 | 75.00 | 29.8114 | 39.8673 |
| 5.19.07.06 | Bere | Qara | 29.50 | 76.67 | 29.8860 | 40.2139 |
| 5.19.07.07 | Calathua | Qalat al-Tuwair | 29.50 | 77.50 | 29.9084 | 40.1942 |
| 5.19.07.08 | Salma | Sihmah | 29.50 | 78.33 | 26.3894 | 47.8292 |

*Table 3. Modern coordinates for known locations in Arabia Felix (Book 6 Chapter 7).*

| Ptolemy ID | Ptolemy Name | Modern Name | Ptol. Lat. | Ptol. Lon. | Mod. Lat. | Mod. Lon. |
|---|---|---|---|---|---|---|
| 6.07.02.04 | Onne | Aynūnah | 28.67 | 66.33 | 28.0933 | 35.1994 |
| 6.07.02.07 | Hippos | Duba | 26.67 | 67.00 | 27.3541 | 35.6834 |
| 6.07.03.03 | Cape Chersonesos | Ra's Abū Madd | 25.67 | 67.00 | 24.8329 | 37.1594 |
| 6.07.03.04 | Iambia | Yanbu | 24.00 | 68.00 | 24.0877 | 38.0635 |
| 6.07.05.05 | Centos | Al Qadeimah | 21.50 | 69.33 | 22.3464 | 39.1497 |
| 6.07.05.07 | Baitios R. mouth | Wadi Fa'idah | 20.67 | 69.50 | 21.9512 | 39.2735 |
| 6.07.05.08 | Baitios R. sources | Wadi Fa'idah | 24.50 | 76.00 | 21.9416 | 39.8404 |
| 6.07.06.02 | Badeo | Al Balad, Jeddah | 20.25 | 70 | 21.4736 | 39.1899 |
| 6.07.06.03 | Ambe | Al Qahma | 19.50 | 70.67 | 18.0002 | 41.6764 |
| 6.07.06.05 | Adedu | Hudayda | 17.17 | 72.25 | 14.7987 | 42.9538 |
| 6.07.07.06 | Muza market | Mocha | 14.00 | 74.50 | 13.3166 | 43.2497 |
| 6.07.07.07 | Sosipu harbor | Dhubab | 13.00 | 74.75 | 12.9426 | 43.4102 |
| 6.07.07.08 | Pseudocelis | Khawr Shūrī | 12.50 | 75.00 | 12.7506 | 43.4755 |
| 6.07.07.09 | Ocelis | Bi'r al Ḥālī | 12.00 | 75.00 | 12.6895 | 43.5084 |
| 6.07.07.10 | Cape Palindromos | Ra's Bab al Mandab | 11.67 | 74.50 | 12.6770 | 43.4622 |
| 6.07.08.05 | Cabubathra M. | Jabal Kahbūb | 11.25 | 76.25 | 12.9378 | 43.6507 |
| 6.07.09.06 | Arabia market | Aden | 11.50 | 80.00 | 12.7791 | 45.0365 |
| 6.07.10.07 | Cane | Qana' | 12.50 | 84.00 | 14.0083 | 48.3217 |
| 6.07.10.09 | Maithath | Mijdahah | 13.00 | 84.33 | 14.0101 | 48.4509 |
| 6.07.10.11 | Prion R. mouth | Wadi Ḥajr | 13.50 | 85.00 | 14.0446 | 48.6772 |
| 6.07.10.12 | Prion R. sources | Wadi Ḥajr | 17.50 | 82.00 | 15.0486 | 47.2685 |
| 6.07.10.13 | Embolon | Burum | 13.50 | 85.50 | 14.3629 | 48.9816 |
| 6.07.10.15 | Thialemath | Salalah | 14.00 | 87.00 | 17.0065 | 54.1399 |
| 6.07.10.16 | Moscha harbor | Khor Rorī (Sumhuram) | 14.00 | 88.50 | 17.0389 | 54.4343 |
| 6.07.11.04 | Ausara | Hasik | 16.75 | 87.33 | 17.4463 | 55.2709 |
| 6.07.11.07 | Neogilla anchorage | Khawr Barr al Ḥikmān, near An Nuqdah | 19.00 | 89.00 | 20.8006 | 58.7194 |
| 6.07.11.08 | Ormanus R. mouth | Batha River | 20.17 | 89.50 | 21.9971 | 59.6583 |
| 6.07.11.13 | Cape Corodamon | Ra's al Hadd | 20.25 | 93.00 | 22.5352 | 59.7941 |
| 6.07.12.02 | Kryptos harbor | Muscat | 21.50 | 92.67 | 23.6154 | 58.5946 |
| 6.07.12.04 | Black M. (Endpoint of seaside) | Ra's Musandam | 22.00 | 93.00 | 26.3827 | 56.5258 |
| 6.07.12.05 | Cape Asabon | Ra's Shuraytah, near Khasab | 23.33 | 92.50 | 26.3868 | 56.3783 |
| 6.07.14.08 | Lar R. mouth | Wadi al Baṯḥā' | 23.50 | 86.50 | 25.6437 | 55.7327 |
| 6.07.14.09 | Lar R. sources | Wadi Sifūnī | 18.00 | 81.00 | 25.0807 | 56.1839 |
| 6.07.17.02 | Ithar | Dārīn | 25.00 | 80.00 | 26.5450 | 50.0763 |
| 6.07.17.03 | Gulf of the Magi | Tarout Bay | 25.33 | 80.00 | 26.7072 | 49.9976 |
| 6.07.18.03 | Cape Chersonesos | Zibārat al Ma'abbar | 26.50 | 80.33 | 27.1903 | 49.3889 |
| 6.07.19.02 | Holy bay | Dawḥat al Musallamīyah | 28.25 | 79.25 | 27.4116 | 49.2643 |
| 6.07.19.05 | Mesanites bay terminus | Ra's aṣ Ṣabīyah | 30.17 | 79.00 | 29.5151 | 48.1677 |
| 6.07.20.11 | Nameless Mtns N. of | Jabal Shams | 22.50 | 88.00 | 23.2364 | 57.2627 |

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|  | Asabon Mtns |  |  |  |  |  |
|---|---|---|---|---|---|---|
| 6.07.27.02 | Aramaua | Ramm | 29.17 | 67.50 | 29.5778 | 35.4146 |
| 6.07.27.05 | Macna | Maqnah | 28.75 | 67.00 | 28.3995 | 34.7465 |
| 6.07.27.07 | Madiama | Al Bad' | 28.25 | 68.00 | 28.4875 | 34.9990 |
| 6.07.28.01 | Achrua | Qurayyah | 28.25 | 70.00 | 28.7827 | 36.0042 |
| 6.07.29.01 | Thaima | Tayma | 27.00 | 71.00 | 27.6340 | 38.5573 |
| 6.07.29.04 | Lugana | Linah | 27.25 | 76.50 | 28.7609 | 43.7380 |
| 6.07.29.06 | Soaca | Shawāq | 26.25 | 68.00 | 27.3532 | 36.4961 |
| 6.07.29.07 | Negran | Madain Saleh | 26.00 | 70.50 | 26.7891 | 37.9518 |
| 6.07.29.08 | Salma | Al Samra | 26.00 | 74.50 | 27.4956 | 41.7181 |
| 6.07.30.04 | Phigeia | Thaj | 26.00 | 79.00 | 26.8726 | 48.7162 |
| 6.07.30.07 | Iabri | Yabrin | 25.00 | 74.50 | 23.2606 | 48.9858 |
| 6.07.31.03 | Aluare | Al Buwayra | 24.25 | 71.00 | 24.9524 | 38.9771 |
| 6.07.31.05 | Salma | Al Yamamah | 24.33 | 73.33 | 24.1867 | 47.3341 |
| 6.07.31.09 | Lathrippa | Medina | 23.33 | 71.67 | 24.4682 | 39.6106 |
| 6.07.32.03 | Catara | Hofuf | 23.33 | 79.50 | 25.3787 | 49.5720 |
| 6.07.32.05 | Macoraba | Mecca | 22.00 | 73.33 | 21.4234 | 39.8250 |
| 6.07.35.03 | Laibris | Ibri | 20.25 | 82.00 | 23.2352 | 56.5060 |
| 6.07.37.01 | Maraba | Marib | 18.33 | 76.00 | 15.4620 | 45.3257 |
| 6.07.37.03 | Nagara | Najran | 18.67 | 81.75 | 17.4899 | 44.1319 |
| 6.07.37.06 | Sylaion | As Sarw | 17.00 | 76.67 | 15.3287 | 44.6919 |
| 6.07.37.08 | Thumna | Am Hajar | 17.25 | 79.00 | 15.0201 | 45.8057 |
| 6.07.38.01 | Vodona | Bidbid | 17.33 | 80.00 | 23.4126 | 58.1265 |
| 6.07.38.02 | Marimatha | Maryama | 17.67 | 85.17 | 15.9609 | 48.8269 |
| 6.07.38.06 | Sabbatha | Shabwah | 16.50 | 77.00 | 15.3684 | 47.0228 |
| 6.07.39.03 | Thabane | Shibam | 16.33 | 85.67 | 15.9264 | 48.6260 |
| 6.07.39.04 | Meiba | Māti' | 15.33 | 74.33 | 14.1582 | 43.3661 |
| 6.07.40.01 | Source of water of Styx | Hammam Damt | 15.00 | 78.00 | 14.0909 | 44.6725 |
| 6.07.41.01 | Mepha | Mayfa'ah | 15.00 | 83.25 | 14.2643 | 47.5717 |
| 6.07.41.03 | Sapphara | Dhafar | 14.50 | 78.00 | 14.2114 | 44.4033 |
| 6.07.41.07 | Thuris | Taizz | 13.00 | 75.25 | 13.5779 | 44.0213 |
| 6.07.41.09 | Hyaila | Ad Dali | 13.83 | 79.00 | 13.6961 | 44.7311 |
| 6.07.43.02 | Aenu I. | Jazīrat Tīrān | 27.33 | 65.75 | 27.9373 | 34.5593 |
| 6.07.43.07 | Ierakon I. | Jebel at Tair | 19.00 | 69.50 | 15.5419 | 41.8353 |
| 6.07.44.02 | Cardamine I. | Kamaran | 16.00 | 71.00 | 15.3568 | 42.5901 |
| 6.07.44.04 | Katakekaumene I. | Jabal Zubayr | 14.50 | 70.50 | 15.0535 | 42.1783 |
| 6.07.44.05 | Malichu Islands (2) | Jabal Zuqar | 14.00 | 71.67 | 13.9981 | 42.7422 |
| 6.07.44.06 | Adanu Islands (2) | Ḥanīsh Islands | 12.50 | 72.50 | 13.7001 | 42.7249 |
| 6.07.45.02 | Agathocleus Islands (2) | Abd al Kuri I. | 10.00 | 81.33 | 12.1780 | 52.2518 |
| 6.07.45.03 | Cocconatu Islands (3) | The Brothers | 9.00 | 83.00 | 12.1416 | 53.0694 |
| 6.07.45.04 | Dioscuri I. (E. end) | Rhiy di-Irīsal | 9.50 | 86.67 | 12.5427 | 54.5341 |
| 6.07.45.05 | Dioscuri I. (W. end) | Ra's Shū'ab | 12.50 | 85.00 | 12.5357 | 53.3063 |
| 6.07.46.02 | Zenobiu Islands (7) | Khuriya Muriya Islands | 16.50 | 91.00 | 17.5050 | 56.0232 |
| 6.07.46.04 | I. of Sarapis | Jazīrat Maṣīrah | 17.50 | 94.00 | 20.4191 | 58.7890 |
| 6.07.47.03 | Ichara I. | Khark I. | 25.00 | 82.00 | 29.2384 | 50.3093 |
| 6.07.47.04 | Tharo I. | Jazīrat Tārūt | 24.75 | 85.25 | 26.5705 | 50.0587 |
| 6.07.47.05 | Tylos I. | Bahrain (Dilmun) | 24.67 | 90.00 | 26.0551 | 50.5524 |
| 6.07.47.06 | Arathos I. | Jazīrat al Muḥarraq | 24.67 | 91.67 | 26.2702 | 50.6301 |

## Appendix B. Tables of Tentatively Identified Points

*Table 4. Modern coordinates for tentatively identified locations in Arabia Petraea (Book 5 Ch. 17).*

| Ptolemy ID | Ptolemy Name | Modern Name | Ptol. Lat. | Ptol. Lon. | Mod. Lat. | Mod. Lon. |
|---|---|---|---|---|---|---|
| 5.17.04.02 | Maliattha | Moaa | 30.50 | 65.75 | 30.5412 | 35.1617 |
| 5.17.04.03 | Calguia | Ajloun | 30.50 | 66.33 | 32.3253 | 35.7274 |
| 5.17.04.04 | Lysa | Kharabat Lussan | 30.25 | 65.83 | 30.4459 | 34.3111 |
| 5.17.04.05 | Gubba | ruins near Themileh | 30.00 | 65.75 | 30.0263 | 34.6640 |
| 5.17.04.05 | Gubba | Faynan | 30.00 | 65.75 | 30.6270 | 35.4940 |
| 5.17.04.05 | Gubba | Quweira | 30.00 | 65.75 | 29.8008 | 35.3157 |
| 5.17.04.06 | Gypsaria | fort near Al Kuntillah | 29.75 | 65.67 | 29.9920 | 34.6892 |
| 5.17.06.03 | Maguza | Ḥammāmāt Māʾīn, near Ad Dabbūsah | 30.75 | 68.00 | 31.6078 | 35.6073 |

*Table 5. Modern coordinates for tentatively identified locations in Arabia Deserta (Book 5 Ch. 19).*

| Ptolemy ID | Ptolemy Name | Modern Name | Ptol. Lat. | Ptol. Lon. | Mod. Lat. | Mod. Lon. |
|---|---|---|---|---|---|---|
| 5.19.01.04 | Boundary mark (Arabia Deserta, Babylonia, Mesopotamia) | | 33.33 | 76.25 | 33.8567 | 42.5400 |
| 5.19.01.11 | Bend of Persian gulf | Khawr Abd Allāh | 30.17 | 79.00 | 29.9000 | 48.4000 |
| 5.19.01.13 | Boundary mark (Arabia Deserta, Arabia Felix) | Ra's al Ard | 29.00 | 79.00 | 29.3522 | 48.1011 |
| 5.19.03.02 | Thapsacus | Ath Thawrah | 35.08 | 73.50 | 35.8363 | 38.5479 |
| 5.19.03.03 | Birtha | ruins near Halabiyah | 35.00 | 73.67 | 35.6893 | 39.8217 |
| 5.19.03.04 | Gadeirtha | near Wadi Kurūdhah | 34.75 | 73.83 | 35.6302 | 39.7930 |
| 5.19.03.05 | Auzara | Zu'ayr | 34.50 | 74.08 | 35.4707 | 39.9887 |
| 5.19.03.06 | Audattha | Ayyash | 34.33 | 74.25 | 35.4196 | 40.0528 |
| 5.19.03.09 | Pharga | Ashara | 34.00 | 75.67 | 34.9222 | 40.5684 |
| 5.19.03.10 | Colarina | Al Karābilah | 33.67 | 75.50 | 34.3803 | 41.0622 |
| 5.19.03.11 | Belgynaia | Al Haqlaniyah | 33.50 | 76.00 | 34.0873 | 42.3652 |
| 5.19.04.02 | Ammaia | Thamāmīyah | 30.17 | 79.00 | 28.5919 | 48.1198 |
| 5.19.04.03 | Idicara | Ra's Kāẓimah | 29.50 | 79.00 | 29.3980 | 47.7435 |
| 5.19.05.06 | Rheganna | Ar Rahaliyah | 33.33 | 75.67 | 32.7656 | 43.3909 |
| 5.19.05.08 | Erupa | Rutba | 31.25 | 72.50 | 33.0397 | 40.2863 |
| 5.19.05.08 | Erupa | Ruḥbah | 31.25 | 72.50 | 33.0438 | 37.3494 |
| 5.19.05.08 | Erupa | Ar Rukbān | 31.25 | 72.50 | 31.4487 | 37.3182 |
| 5.19.06.01 | Themme | 'Ayn Tamr | 31.67 | 75.00 | 32.5669 | 43.4885 |
| 5.19.06.06 | Sora | Suwayr | 30.33 | 75.00 | 30.1133 | 40.3894 |
| 5.19.06.07 | Odagana | Ābār al Wuqubá | 30.67 | 76.25 | 28.7794 | 45.5512 |
| 5.19.06.07 | Odagana | Qalīb Ḥadājān | 30.67 | 76.25 | 29.2999 | 39.3333 |
| 5.19.06.08 | Tedion | Hafar Al Batin | 30.50 | 77.00 | 28.4314 | 45.9628 |
| 5.19.06.09 | Zagmais | Zahwah | 30.17 | 76.50 | 29.6864 | 42.1046 |
| 5.19.06.10 | Arrade | Rafha | 30.25 | 76.50 | 29.6365 | 43.5240 |
| 5.19.07.03 | Banacha | Ghīrān al Banāt | 29.92 | 73.25 | 29.6473 | 39.5651 |
| 5.19.07.05 | Alata | al-Rajajeel | 29.50 | 75.67 | 29.8127 | 40.2195 |

*Table 6. Modern coordinates for tentatively identified locations in Arabia Felix (Book 6 Chapter 7).*

| Ptolemy ID | Ptolemy Name | Modern Name | Ptol. Lat. | Ptol. Lon. | Mod. Lat. | Mod. Lon. |
|---|---|---|---|---|---|---|
| 6.07.02.05 | Modiana | Al Muwaylih | 27.75 | 66.67 | 27.6825 | 35.4764 |
| 6.07.03.01 | Phoenicum | Al Wajh | 26.33 | 67.33 | 26.2265 | 36.4580 |
| 6.07.03.02 | Rhaunathi | Khurraiyim Sa'id | 25.67 | 67.25 | 25.8564 | 36.7422 |
| 6.07.05.03 | Arga | Ar Rayis | 22.67 | 69.00 | 23.5734 | 38.6046 |
| 6.07.05.04 | Zabram | Rabigh | 22.00 | 69.33 | 22.7982 | 39.0326 |
| 6.07.05.06 | Thebai | Thuwal | 21.00 | 69.67 | 22.2806 | 39.1118 |
| 6.07.06.04 | Mamala | Jazan | 18.17 | 71.75 | 16.8872 | 42.5605 |
| 6.07.07.03 | Ailu | Al Jāḥ al A'lá | 16.50 | 73.50 | 14.3461 | 43.0750 |
| 6.07.07.05 | Sakatia | Al Khawkah | 14.50 | 74.25 | 13.8070 | 43.2478 |
| 6.07.08.03 | Cape of Poseidon | Jabal Ḥasīs | 11.50 | 75.00 | 12.6821 | 43.5227 |
| 6.07.08.04 | Sanina | Summānah | 11.50 | 75.50 | 12.7348 | 43.6304 |
| 6.07.09.02 | Madoce | Wadi Ma'dah | 11.75 | 77.00 | 12.6458 | 44.1863 |
| 6.07.09.03 | Mardache | Marāziqah | 11.75 | 78.00 | 12.7019 | 44.2999 |
| 6.07.09.05 | Cape of Ammon | Ra's Abū Qiyāmah | 11.50 | 79.33 | 12.7292 | 44.8926 |
| 6.07.09.07 | Agmanisphe | Umm 'Aṣlah | 11.75 | 80.67 | 13.2069 | 45.4645 |
| 6.07.09.08 | Black M. | Jabal al 'Urays | 11.75 | 81.50 | 13.5132 | 45.9332 |
| 6.07.10.02 | Abisama | Al Busṭī | 11.75 | 82.00 | 13.5003 | 46.6880 |
| 6.07.10.04 | Mada | Al Mijda | 11.50 | 83.00 | 13.9246 | 47.7650 |
| 6.07.10.05 | Eristhe | Balhaf | 11.75 | 83.50 | 14.0015 | 48.1824 |
| 6.07.10.08 | Trulla harbor | Bi'r Ali | 12.67 | 84.00 | 14.0234 | 48.3434 |
| 6.07.10.10 | Prionoton M. | Jabal Yikūd | 13.00 | 84.67 | 14.1634 | 48.5458 |
| 6.07.10.14 | Tretos harbor | Ash Shihr | 13.75 | 86.33 | 14.7573 | 49.6060 |
| 6.07.10.14 | Tretos harbor | Al Mukallah | 13.75 | 86.33 | 14.5414 | 49.1253 |
| 6.07.10.17 | Cape Syagros | Ra's Raysūt | 14.00 | 90.00 | 16.9345 | 54.0089 |
| 6.07.11.05 | Agke | Sawqirah | 17.50 | 87.50 | 18.1588 | 56.5371 |
| 6.07.11.09 | Didyma Mtns | Jabal Ja'alān | 19.33 | 90.25 | 22.1952 | 59.3677 |
| 6.07.11.10 | Coseude | As Suwayḥ | 20.00 | 91.00 | 22.0864 | 59.6867 |
| 6.07.11.11 | Oracle of Artemis | Al Khaddah | 20.00 | 91.67 | 22.1254 | 59.7183 |
| 6.07.11.12 | Abissa | Ar Ru'ays | 20.25 | 92.33 | 22.1781 | 59.7648 |
| 6.07.14.06 | Rhegama | Al Jazira Al Hamra | 23.17 | 88.00 | 25.7088 | 55.7972 |
| 6.07.14.07 | Cape of Sacred Sun | Ra's Abū Aḥmad | 23.50 | 87.33 | 25.7204 | 55.7988 |
| 6.07.14.10 | Capsina | Jazīrat as Sīnīyah | 23.17 | 86.00 | 25.6126 | 55.6383 |
| 6.07.14.11 | Cauana | ed-Dur | 23.00 | 85.00 | 25.5252 | 55.6276 |
| 6.07.15.02 | Sarcoe | Sharjah | 23.00 | 84.25 | 25.3568 | 55.3905 |
| 6.07.15.03 | Carada | Karranah | 23.50 | 83.67 | 26.2340 | 50.5215 |
| 6.07.15.04 | Atta | Ra's al Khaththāq | 23.25 | 82.00 | 26.0402 | 50.1505 |
| 6.07.16.02 | Magindanata | Al Qatif | 23.33 | 81.00 | 26.5562 | 49.9960 |
| 6.07.16.03 | Gerra | Al 'Uqayr | 23.33 | 80.00 | 25.6444 | 50.2146 |
| 6.07.16.04 | Bilbana | Bi'r Abū 'Idbūlah | 24.17 | 80.00 | 26.2594 | 50.0602 |
| 6.07.17.04 | Istriana | Dosariya | 25.67 | 80.00 | 26.9211 | 49.7436 |
| 6.07.18.02 | Mallada | Mardumah | 26.17 | 80.17 | 27.1086 | 49.4815 |
| 6.07.18.04 | Leanites bay | Dawḥat ad Dafī | 27.00 | 79.75 | 27.2248 | 49.4253 |
| 6.07.19.03 | Coromanis | Ra's Karmah | 28.75 | 79.00 | 27.7324 | 48.8187 |
| 6.07.20.01 | Zames Mtns (middle) | Jibāl Salmá | 25.00 | 76.00 | 27.0975 | 42.1236 |
| 6.07.20.02 | Mareitha Mtns | Asmar Mtns | 21.50 | 80.50 | 25.4937 | 42.7448 |
| 6.07.20.02 | Mareitha Mtns | Jabal Mahrāt | 21.50 | 80.50 | 16.7333 | 52.7667 |
| 6.07.20.03 | Climax Mtns | Jabal al Qullah | 16.00 | 76.50 | 14.3119 | 44.2873 |
| 6.07.27.04 | Thapaua | Khabrat al 'Assafiyah | 29.00 | 71.67 | 28.2675 | 38.9786 |
| 6.07.27.06 | Agcale | Al Qalibah | 28.75 | 68.25 | 28.3840 | 37.6914 |
| 6.07.28.02 | Obraca | Abraq al Rukhaymah | 28.33 | 71.50 | 28.2232 | 39.0224 |
| 6.07.28.04 | Pharatha | Buraydah | 28.67 | 73.67 | 26.3190 | 43.9717 |
| 6.07.28.05 | Satula | Subaysiyah | 28.17 | 77.50 | 28.8788 | 47.9132 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6.07.28.06 | Laba | Bi'r al Badī'ah | 27.67 | 68.17 | 27.5078 | 36.3303 |
| 6.07.29.02 | Gaia | Ghayl al-Waggag | 27.33 | 71.25 | 27.7816 | 38.6693 |
| 6.07.29.03 | Aina | Unayzah | 27.33 | 75.67 | 26.0937 | 43.9819 |
| 6.07.29.05 | Gaisa | Ghanwa | 27.25 | 78.67 | 27.0185 | 48.4578 |
| 6.07.30.01 | Arre | Birāk al 'Arā'ish | 26.17 | 75.67 | 28.4891 | 43.3373 |
| 6.07.30.02 | Digema | Rumah | 26.50 | 77.00 | 25.5616 | 47.1617 |
| 6.07.30.03 | Saphtha | Ain Safawi | 26.33 | 78.25 | 27.5272 | 47.6822 |
| 6.07.30.05 | Badais | Bada | 25.50 | 68.50 | 26.8379 | 36.9060 |
| 6.07.30.06 | Ausara | Al Bi'r al Jadīd | 25.50 | 71.00 | 26.0116 | 38.5981 |
| 6.07.30.08 | Alata | Al Ajfar | 25.50 | 77.33 | 27.4737 | 42.9950 |
| 6.07.31.01 | Mochura | Umm Dharb | 24.50 | 69.67 | 25.6254 | 38.4313 |
| 6.07.31.02 | Thumna | Hadiyah | 24.83 | 71.17 | 25.5393 | 38.7415 |
| 6.07.31.07 | Marata | Um Rabia | 24.33 | 79.33 | 26.0228 | 48.8520 |
| 6.07.31.08 | Ibirtha | Ābār 'Irj | 24.67 | 79.33 | 26.3628 | 48.8068 |
| 6.07.31.10 | Carna | Al Mudiq | 23.25 | 73.50 | 21.6762 | 40.1357 |
| 6.07.31.10 | Carna | Ash-Shafa | 23.25 | 73.50 | 21.0699 | 40.3107 |
| 6.07.32.01 | Biabanna | Uyayna | 23.00 | 76.50 | 24.9036 | 46.3791 |
| 6.07.32.02 | Giratha | Haradh | 23.00 | 77.67 | 24.1470 | 49.0573 |
| 6.07.32.04 | Baiba | Baḥwil | 22.50 | 71.50 | 22.4277 | 39.4305 |
| 6.07.32.04 | Baiba | Al Abwa | 22.50 | 71.50 | 23.1159 | 39.1119 |
| 6.07.33.01 | Sata | Sadus | 22.33 | 81.17 | 24.9940 | 46.2079 |
| 6.07.33.02 | Masthala | Al Muqaṭṭarah | 22.50 | 81.75 | 24.2669 | 54.5618 |
| 6.07.33.02 | Masthala | Al 'Uqaylah | 22.50 | 81.75 | 23.9142 | 52.6754 |
| 6.07.33.02 | Masthala | Mezairaa | 22.50 | 81.75 | 23.1376 | 53.7813 |
| 6.07.33.04 | Atia | Afi | 22.25 | 85.00 | 23.4532 | 57.8089 |
| 6.07.33.04 | Atia | Khatt | 22.25 | 85.00 | 25.6091 | 56.0088 |
| 6.07.33.05 | Rhabana | Ibra | 22.00 | 87.00 | 22.6862 | 58.5331 |
| 6.07.33.06 | Chabuata | Abu Dhabi | 22.00 | 79.25 | 24.4660 | 54.3665 |
| 6.07.33.07 | Thumata | Thamūdah | 21.33 | 77.67 | 21.5560 | 40.8442 |
| 6.07.34.01 | Olaphia | Al Abwa | 21.75 | 77.67 | 23.1159 | 39.1119 |
| 6.07.34.01 | Olaphia | Doghaibejah | 21.75 | 77.67 | 22.5943 | 41.3589 |
| 6.07.34.01 | Olaphia | Al 'Ulayyah | 21.75 | 77.67 | 19.6196 | 41.9714 |
| 6.07.34.02 | Inapha | Diriyah | 21.67 | 79.17 | 24.5903 | 46.7091 |
| 6.07.34.03 | Tiagar | Ţawī al Qaran | 21.33 | 85.00 | 25.5332 | 55.7475 |
| 6.07.34.04 | Appa | Al Kamil Wal Wafi | 21.00 | 91.00 | 22.2174 | 59.2019 |
| 6.07.34.04 | Appa | Afi | 21.00 | 91.00 | 23.4532 | 57.8089 |
| 6.07.34.05 | Agdamu | Al Mathnah | 20.33 | 73.50 | 21.2672 | 40.3859 |
| 6.07.34.06 | Carman | Al Manzil | 20.25 | 75.25 | 19.2729 | 41.9650 |
| 6.07.35.02 | Nascos | Al Bayḏā' | 20.67 | 81.25 | 30.0232 | 40.1712 |
| 6.07.35.04 | Lattha | Lamḥah | 20.25 | 83.33 | 25.4546 | 55.7979 |
| 6.07.35.04 | Lattha | Al Malaiha | 20.25 | 83.33 | 25.1171 | 55.8716 |
| 6.07.36.02 | Albana | Al Bāḥah | 19.25 | 74.50 | 20.0112 | 41.4673 |
| 6.07.36.02 | Albana | Abha | 19.25 | 74.50 | 18.2140 | 42.5048 |
| 6.07.36.02 | Albana | Old Bani Saad | 19.25 | 74.50 | 20.9290 | 40.7989 |
| 6.07.36.03 | Chargatha | Kharābāt Hamdān | 19.25 | 76.17 | 16.1595 | 44.7641 |
| 6.07.36.03 | Chargatha | Kharid | 19.25 | 76.17 | 16.7446 | 44.7014 |
| 6.07.36.04 | Laththa | Layla | 19.33 | 75.33 | 22.2911 | 46.7357 |
| 6.07.36.05 | Omanum market | Ajman | 19.33 | 77.67 | 25.4109 | 55.4350 |
| 6.07.37.04 | Iula | Al Huwaylah | 18.25 | 85.33 | 15.4845 | 48.3314 |
| 6.07.37.05 | Magulaua | Sana'a | 17.00 | 75.50 | 15.3557 | 44.2134 |
| 6.07.38.03 | Sabe | Zabid | 16.92 | 73.67 | 14.1948 | 43.3153 |
| 6.07.38.03 | Sabe | Shibam | 16.92 | 73.67 | 15.5092 | 43.9032 |
| 6.07.38.04 | Menambis | Dhamar | 16.50 | 75.75 | 14.5474 | 44.4040 |
| 6.07.38.05 | Thabba | Qa'tabah | 16.17 | 78.67 | 13.8553 | 44.7057 |
| 6.07.38.05 | Thabba | Shabwah | 16.17 | 78.67 | 14.5440 | 45.9097 |
| 6.07.39.01 | Madasara | As Sadarah | 16.33 | 81.75 | 14.4899 | 48.0881 |
| 6.07.39.02 | Gorda | Wadi Jardan | 16.00 | 82.50 | 15.0616 | 46.8560 |

| 6.07.40.02 | Draga | Rada'a | 15.25 | 79.17 | 14.4164 | 44.8416 |
|---|---|---|---|---|---|---|
| 6.07.41.02 | Saraka | Sharja | 14.50 | 75.50 | 13.4345 | 43.9263 |
| 6.07.41.04 | Are | Yarim | 14.50 | 80.50 | 14.2960 | 44.3769 |
| 6.07.41.05 | Rhaida | Mahmeddah | 14.17 | 83.67 | 14.4742 | 48.4510 |
| 6.07.41.06 | Bainun | Kaninah | 14.25 | 84.50 | 14.4977 | 48.3474 |
| 6.07.41.08 | Lachchere | Laḥij | 13.33 | 77.50 | 13.0595 | 44.8788 |
| 6.07.41.10 | Maccala | Mukayris | 13.75 | 81.00 | 13.9427 | 45.6729 |
| 6.07.41.10 | Maccala | Al Mukalla | 13.75 | 81.00 | 14.5414 | 49.1253 |
| 6.07.41.11 | Sachle | As Safra' | 13.33 | 82.67 | 13.5323 | 44.8595 |
| 6.07.42.01 | Sabe | Jabal Şabir | 13.00 | 76.00 | 13.5182 | 44.0522 |
| 6.07.42.01 | Sabe | As Sawā'il | 13.00 | 76.00 | 13.8215 | 44.3060 |
| 6.07.42.01 | Sabe | Ash Shi'bah | 13.00 | 76.00 | 13.3379 | 43.9679 |
| 6.07.42.03 | Sochchor | Ash Shihr | 12.67 | 78.50 | 14.7573 | 49.6060 |
| 6.07.42.04 | Bana | Al Fahn | 12.67 | 80.33 | 13.2015 | 45.2887 |
| 6.07.43.03 | Timagenes I. | Al Ḥasānī I. | 25.75 | 66.00 | 24.9658 | 37.0876 |
| 6.07.43.05 | I. of Daemons | Island near Abū Shayţānah | 23.25 | 66.75 | 23.8211 | 38.2670 |
| 6.07.43.06 | Polybiu I. | Aika I. | 21.67 | 67.67 | 22.0238 | 38.9725 |
| 6.07.45.04 | Dioscuri | Qashio | 9.50 | 86.67 | 12.6071 | 53.8628 |
| 6.07.45.06 | Trete I. | Barrāqah I. | 12.00 | 86.50 | 13.9799 | 48.4613 |
| 6.07.46.03 | Organa I. | Jazīrat Shaghaf | 19.00 | 92.00 | 20.4590 | 58.7485 |
| 6.07.47.02 | Apphana I. | Jazīrat Faylakā | 28.67 | 81.33 | 29.4389 | 48.3344 |
| 6.07.47.02 | Apphana I. | Abadan I. | 28.67 | 81.33 | 30.3430 | 48.2854 |
| 6.07.47.02 | Apphana I. | Jazīrat Būbiyān | 28.67 | 81.33 | 29.7688 | 48.2562 |