

Charting Arabic Cryptology's Evolution*

KATHRYN A. SCHWARTZ

Abstract This article presents the evolution of the Arabic cryptologic treatises discovered in Istanbul's Süleymaniye library, linking its various phases to the greater bureaucratic trends of the regimes which produced these treatises.

Keywords 'Abbāsid, Arabic cryptanalysis, Arabic cryptology, *Arabic Origins of Cryptology*, Ayyūbid, Mamlūk, Middle East, Süleymaniye treatises

Introduction

The 1980 discovery of several Arabic cryptologic treatises in Istanbul's Süleymaniye library¹ substantiated David Kahn's 1967 claim that "cryptology was born among the Arabs" [19, p. 93]. Although Kahn suspected that Arabic cryptologic investigation began during the 14th century under 'Ali ibn Muḥammad ibn ad-Durayhim (b. 1312–d. 1361), the Süleymaniye treatises establish that the world's first extant cryptologic treatise is Ya'qūb ibn Ishāq al-Kindī's (d. 873) 9th-century text, and suggest the earliest nonextant text as that of al-Khalīl ibn 'Aḥmad al-Farāhīdī (d. 776) [27, p. 35, vol. 1].²

Under the initiative of the Saudi 'King Faisal Centre for Research and Islamic Studies,' many of these treatises have been transcribed into typed Arabic. Since 2003, a team of scholars, known here as Mrāyātī *et al.*, has translated abridged versions of select Süleymaniye treatises into English, thus fār producing six volumes in a series entitled *Arabic Origins of Cryptology*.³ Each volume summarizes the treatises' cryptologic contributions and offers English translations of the chosen sections alongside the original Arabic. This article does not recapitulate Mrāyātī *et al.*'s works, rather it proposes to broadly chart medieval Arabic cryptology's evolution by analyzing the wider historic trends surrounding the content of Mrāyātī *et al.*'s six volumes.⁴

Most advanced civilizations before the 9th-century used cryptology; however, the Arabs were the first to develop a "sustained" form of cryptanalysis [19, p. 93]. That is, as the Süleymaniye treatises attest, the Arabs were the first to define

*2009 Winner of the Undergraduate Paper Competition in Cryptology.

Address correspondence to Kathryn A. Schwartz, 4 Evergreen Row, Armonk, NY 10504, USA. E-mail: kaschwartz@gmail.com

¹These treatises shall herein be referred to as the Süleymaniye treatises.

²All dates are in A.D., unless otherwise noted.

³Should the reader be interested in pursuing these texts, they should contact the 'King Faisal Centre for Islamic Studies' to purchase copies of the volumes. For a review of these volumes, see [25].

⁴For further discussion of this topic, e-mail the author for electronic copies of an extended essay.

cryptanalysis and to systematically develop and record processes for cryptanalysing cryptograms.

Empirical Evidence for Arabic Cryptology

While evidence for Arabic cryptanalysis remains lost outside of the Süleymaniye treatises, empirical evidence for Arabic cryptography survives. Enciphered Arabic and Hebrew amulets from a long-forgotten storeroom in a Cairo synagogue, now known as the Cairo Genizah, were recovered in the late 19th-century and attest to cryptography's use at the popular level during the 11th-century [6]. Furthermore, an Arabic codex discovered in Gotha by the German scholar Ferdinand Wüstenfeld suggests a 14th-century Egyptian military reliance on cryptography, as the volume contains a cryptogram on warfare tactics [7, p. 19]. Additionally, this author found a 1940 account of trading aboard a Gulfi dhow by Alan Villiers that describes a 13th-century process for encrypting hand-signals [34, p. 361; 16, p. 119]. These chronologically and geographically scattered findings demonstrate cryptography's extent amongst the Arabs. Such cryptographical evidence corroborates the Süleymaniye treatises' contents and fosters hope that practical evidence for cryptanalysis exists. However, in lieu of such evidence, cryptologic treatises must be mined for tangible connections to actual cryptanalytical application so that a map of Arabic cryptology may be charted.

Charting Arabic Cryptology's Evolution

Kahn argued that studying cryptology demands focusing on external factors and "the big picture" to chart its progression [20]. This is crucial when analyzing Arabic cryptology due to the absence of cryptanalysed correspondence, the geographically and chronologically scattered origins of cryptologic evidence, and the few secondary sources available. Cryptology's European evolution originated after scholarly investigation, developed through courtly life, and was rejuvenated through wartime pressures. Arabic cryptology's progression responded to similar stimuli.

The Süleymaniye treatises, all produced by scribes holding official positions, range in date of composition from the 9–14th centuries. As traced through the biographies of their authors, the earlier treatises originated from 9–13th-century 'Abbāsid Baghdad, while later ones arose from the governments of the 12–13th-century Egyptian and Syrian Ayyūbids and the 13–16th-century Egyptian Mamlūks.⁵ The linguistically and technically interconnected nature of the writings suggests that cryptology was a perpetual science. Nonetheless, the varying

⁵It is presumed that the Süleymaniye treatises were subsequently gathered by the Ottomans. This is because they were separated from larger administrative encyclopedic volumes and stored together in the Empire's capital, Istanbul, and because the Ottomans are known to have relied heavily on cryptology [7, p. 20]. The Ottoman Empire, which lasted from 1299–1923, came to rule vast territories which stretched from North Africa to the Middle East, and included much of Southeastern Europe. Baghdad, Syria, and Egypt, from which the Süleymaniye treatises hail, all belonged to the Ottoman Empire at one point. Therefore, future investigations may determine a relationship between the Ottoman and Arabic cryptologic traditions.

orientations of the governments and their times directly influenced cryptology's development and account for cryptology's differing phases.⁶

The 758 founding of the 'Abbāsīd Caliphate marked the first Muslim dynasty to focus less on imperial expansion and more on cultivating an organized capital and heralded a golden era of advanced scholastic and cultural investigation. As such, cryptology thrived under the 'Abbāsīds (758–1258): the science arose through their efforts to unlock ancient knowledge, it was advanced by 'Abbāsīd courtiers who paired it with poetry for recreation, and it became an administrative fixture with the development of 'Abbāsīd government offices. Under the late Ayyūbid dynasty (1171–1250) and Mamlūk Sultanate (1250–1517), administrative cryptology evolved to reflect the militarization of these two bureaucracies. Although military preoccupations were suppressed for a time under the 'Abbāsīds, in 836 the caliph switched his capital from Baghdad to Samarra to live amongst his soldiers, thereby re-empowering the military. Its influence came to a head under the later Ayyūbids and Mamlūks, whereupon administrative offices fell under military control. Accordingly, the treatises produced during this era imply cryptology's use in espionage. In all then, three differently orientated, yet nonetheless overlapping cryptologic phases emerge from the Süleymaniye treatises. They are cryptology's academic foundations, its expansion through poetic application, and its implementation as a covert administrative tool.

The 'Abbāsīd Renaissance and Cryptology's Academic Roots

The official emphasis placed on learning and the multidisciplinary style of education under the 'Abbāsīds gave rise to cryptology. A hub of refinement, Baghdad provided stability and tolerance for multicultural exploration. Scholarly investigation was officially encouraged, and the culture championed polymathic learning [14, p. 499–504]. Believing in the cumulative nature of knowledge, early 'Abbāsīds patronized scholars and paid handsomely for translations [9, p. 54]. These translations spurred the contemporary scientific, legal, philosophical, and religious debates [11, p. 494]. Notable administrative families supported intellectuals privately, while institutions like the House of Wisdom, founded in 832, received funding from the Caliphate. Established exclusively for translating the Greek, Sanskrit, Syriac, Hebrew, and Middle Persian works of the Storehouse of Wisdom, the House of Wisdom fostered the 300 year 'Abbāsīd translation movement [11, p. 480].

Because many books contained dead languages, translators treated such writings as ciphertexts [18, p. 99]. The drive to render encrypted foreign religious and alchemical texts into Arabic forced translators to work directly as cryptanalysts [5]. Due to cryptology's closeness to the translation movement, many linguistic and mathematical traces of the translation movement exist within the Süleymaniye treatises. Concerning linguistics, the translation movement's incorporation of previous societies' achievements encouraged the analysis and expansion of Arabic through the naming and elaboration of borrowed concepts [13, p. 249; 33, p. 62]. Such intralinguistic scrutiny survives in the cryptologic treatises through disagreement over

⁶The Süleymaniye treatises do not indicate which administrative offices used cryptology, and there is no evidence of an exclusive cryptologic government division. It is conjectured that cryptology fell under the chanceries of the 'Abbāsīds Ayyūbids, and Mamlūks, since they presided over the departments of confidential affairs and the post.

coining new terminology, as authors offered different terms for concepts like ‘plaintext,’ ‘ciphertext,’ and ‘key’ [27, pp. 24–25, vol. 1]. Mathematically, the translation of Sanskrit texts exposed the Arabs to Hindu-Arabic numerals and the concept of zero [22, p. 15]. Due to the cryptanalytical necessity for statistical and combinatorial analyses, this numerical system was crucial to cryptology’s development.

The scientific pursuits of the era prominently featured the combination of philology and mathematics. This pairing formed the basis of Arabic cryptanalysis, as seen through the earliest Süleymaniye treatise, written by al-Kindī. Citing his scholarly motivation to unlock the secrets of the ancients as “those who neglect cryptology will not benefit from their work, and will not have a deep understanding of scientific achievements,” al-Kindī’s cryptanalytical methods relied on two contemporary mathematical discoveries: combinatorial and statistical analysis [21, pp. 119–121]. Combinatorial analysis, or quantifying potential combinations, originated under al-Khalīl’s (d. 776) pursuit to calculate the number of words in the Arabic language for his *Book of the (Letter) ‘Ayn*, the first Arabic dictionary [28].⁷ Like al-Khalīl’s endeavor, cryptology too attempted to quantify linguistic boundaries to create guidelines for the cryptologist. Hence al-Kindī aspired to assess and categorise Arabic’s features through bigrams, trigrams, and incompatible letters. Like combinatorial analysis, statistical analysis also resulted from pairing philology and mathematics. Originating in al-Kindī’s treatise, this was devised for the cryptanalytical purpose of comparing letter frequencies from Arabic plaintexts to their counterparts from Arabic cryptograms [18, p. 101]. Thus combinatorial and statistical analysis, which remain essential to cryptanalysis, arose from the multidisciplinary nature of ‘Abbāsīd learning and account for the Arabs’ pivotal cryptologic role.

The ‘Abbāsīd Court: Pairing Cryptology and Poetry for Amusement and Its Effects

The ‘Abbāsīd academic movement began in conjunction with its bureaucratisation. Creating a refined court life that thrived as a cultural hotbed, the desire to showoff sophistication accounted for a rejuvenation of poetic stylings [14, p. 532]. Poetic cryptology, which al-Kindī briefly discussed, gained popularity amongst courtly scribes between the 10–13th centuries. Poetic ciphers functioned like today’s crossword puzzles to highlight the fine education and diverse specialties of their practitioners. Intended for recreational use, the impetus for the poetic Süleymaniye treatises differed from that of al-Kindī’s scholarly endeavor. Composed in the formal style of contemporary administrative texts and addressed to nameless patrons, these treatises existed to enlighten the uninformed on the methodology of this challenging hobby.

⁷The 9–10th centuries marked an increased interest in the Arabic language, originating from the desire to linguistically contextualise the Qur’ān [33, pp. 58–59; 8, p. 106]. Focus on Arabic lexicography produced several dictionaries and thesauri, formatted in numerous ways to “demonstrate the possibilities for word games that the very wealth of the Arabic language affords” [7, p. 17; 8, p. 107]. For example, some dictionaries worked along rhyme schemes to best aid the poet’s hunt for metrically appropriate words [23, p. 94]. Grammatical studies also featured prominently in the scholarship of the early ‘Abbāsīds [8, p. 115]. As lexicographical and grammatical protocol structured the organization of Arabic words, this linguistic codification aided cryptanalysis and cryptography.

Poetic cryptanalysis, which worked to crack enciphered poems, relied on statistical letter frequency and combinatorial analysis, in conjunction with the metrical rules of traditional Arabic rhyme schemes. Their short length and the potential for various plaintexts suggests that these cryptographic puzzles were used to test and frustrate their enthusiasts, rather than to relay enciphered but ultimately intelligible exchanges. Despite its leisurely provenance, poetic cryptology played a pivotal role in developing Arabic cryptology as a whole. Firstly, the purposely confounding nature of poetic cryptology advanced the quest to delineate Arabic's trends and rarities. Secondly, the structure of the poetic treatises set the standard for all subsequent treatises. Their goal of educating those ignorant of cryptology's methods accounted for their distinctive organization and comprehensibility. As such, successive Süleymaniye treatises concerning cryptology's official use for affairs of state adopted this pedagogical format to train scribes. Thirdly, poetic cryptology's popularity encouraged a bureaucratic backlash, which attacked poetic cryptology for its uselessness and indiscretion, and fostered prose cryptology's official use [29, p. 105; 24, p. 55]. While administrators initially espoused poetic cryptology in their bid to join the court, the increasing bureaucratisation of the 'Abbāsids marked cryptology's application as a predominantly official science. As a government instrument, dissemination of its methodology threatened the state by complicating cryptanalytical techniques. Finally, the stealth cryptographic methods of the poetic treatises, namely steganographic ciphers first devised to taunt, became valuable fixtures in the later treatises composed by militarized bureaucracies.

The Rise of Militarized Bureaucracies: Cryptology's Links to Espionage

Official military mobilization had been a developing trend for several centuries; however, only under the later Ayyübid and Mamlük regimes did administrative offices succumb to military control.⁸ Accordingly, treatises produced under the Ayyübid and Mamlüks embodied the concerns voiced by the bureaucratic cryptologists over maintaining cryptology's secrecy for tactical purposes. Developing the steganographic ciphers of the poetic treatises, alluding to cryptology's professionalisation, and familiarising the cryptanalyst with foreign languages like Frankish, Greek, and Mongol, these treatises suggest cryptology's use in espionage.⁹ They therefore

⁸Despite these changes of governments, the treatises of the 'Abbāsids, Ayyübid, and Mamlüks all hailed from relatively unvarying administrative offices. 'Abbāsid administrative offices were replicated under the Egyptian Fātimids (909–1171), and the successive Ayyübid and Mamlük administrative offices "suggest no real cleavages" since "continuity in administrative institutions tend to be stronger than changes of governments" [15, p. 68; 12]. This continuity is supported by the interconnected nature of the cryptologic treatises and justifies assessment of the Süleymaniye treatises as a progressive whole.

⁹Bureaucratic concern for foreign territories began during the 10–13th centuries through the proliferation of travel and geographic literature undertaken in search of knowledge [1, p. 258; 23, p. 96]. It heightened under the Ayyübid and Mamlüks, whose interests in external politics are well-documented. Chancery exchanges verify that these regimes held religious, diplomatic, military, and mercantile interests abroad [2]. Cryptologic treatises indicate that the Ayyübid and Mamlüks likely exploited cryptology to monitor foreign politics. This is corroborated by Mamlük practices, like dispatching ambassadors to European courts for reconnaissance within extensive intelligence systems under rulers like al-Malik al-Nāṣir (d. 1341) [4, p. 18, 33].

relate to the reconnaissance stressed through contemporary Mamlük military literature and the Mamlük's sensitivity to their postal service's strategic importance.

Created for administrative purposes, the postal service's incorporation into the 'Abbāsīd and Mamlük Empires heralded the large-scale exchange of messages over great expanses.¹⁰ Reaching its height under the 14th-century Mamlüks, it united the Sultanate though its employ of pigeons, camels, mules, and footmen until its 15th-century demise [30, p. 85; 10, p. 5]. The Mamlüks hired only the most trustworthy men to convey their state secrets, and the many transferals between workers entailed for the delivery of each message corroborates cryptology's official necessity during this era [30, p. 18]. The postal service's official function evolved over time. Though first used administratively by the 'Abbāsīds, under the Mamlüks it served military purposes as mailmen gathered intelligence on the villages they served, and army officers were assigned to the postal service [26, pp. 78–79, 501; 17, pp. 195–196]. Furthermore, while the 'Abbāsīd postal service was controlled by the director of the post department, who in turn reported to the vizier, the Mamlük postal service functioned under the secretary of state, who deferred to the military chief [32; 12]. Referring to it as their secret weapon, the Mamlük saying 'the postal service grants victory' linked this cryptologically enabling system to military intelligence aims [30, p. 27]. Stress on reconnaissance also abounds in Mamlük military literature.

Mamlük military literature covered strategic warfare, weapons, and courtly tactical warfare [31, p. 27]. It emphasized intelligence gathering because "the chivalric impetuosity of the Christian warrior appeared less than laudable against the intelligent policy of caution [of] . . . the Muslims" [31, p. 29]. Courtly manuals on war, like "Alleviation of Worries on the Planning of War," by 'Umar ibn 'Ibrāhīm al-'Awsī al-'Anṣārī (d. 1406), stressed the need for reconnaissance and demonstrated the existence of intelligence systems [3, p. 9, 12]. In al-'Anṣārī's tract, sections entitled "On Scouts and Spies and What Concerns Them" and "What Traits about Good Scouts are Necessary . . ." preceded those on combat [3, pp. 17–27]. Referring to professionalized espionage, foreign languages, and codes, writings such as this mirror the emphasis on reconnaissance and secrecy which characterizes the Ayyūbīd and Mamlük cryptologic treatises.

Conclusion

Each cryptologic phase influenced the techniques of its successor. The poetic treatises attempted to thwart the academic treatises' cryptanalytical innovations by developing confounding ciphers to tease its practitioners. Enjoying much popularity, poetic cryptology catalyzed a bureaucratic backlash as cryptology grew more important to the state. Yet despite rejecting poetic cryptology for its irrelevance and foolhardiness, the bureaucratic treatises adopted the pedagogical styling of their poetic rivals and developed their methodology. Presumably due to these pedagogical treatises' efficacy, the treatises of the militarized bureaucracies attempted to make their techniques increasingly impenetrable. In so doing, they returned to the

¹⁰Diverted by the Crusades, the Ayyūbīds never developed a postal service [32]. Furthermore, as "only a few court and administrative posts were held by military men," the Ayyūbīds did not produce much military literature [15, p. 83]. Because the Ayyūbīd Süleymaniye treatises shaped the Mamlük treatises, and these writings derive from corresponding administrative offices, both are herein related to the Mamlük postal service and their military literature.

steganographic tactics of the poetic treatises, whose stealth innovations proved useful in achieving this aim.

Despite the limited secondary information available on Arabic cryptology, the Süleymaniye treatises indicate the diverse ways in which cryptology was administratively applied under the 'Abbāsids, Ayyūbids, and Mamlūks, and relate closely to the bureaucratic trends of the 9–14th centuries. It is hoped therefore that more studies and initiatives will be undertaken to research and develop the field of Arabic cryptology. These will enhance knowledge of Middle Eastern and cryptologic history.

About the Author

Kathryn A. Schwartz graduated from the University of Cambridge in 2008, with a B.A. in Middle Eastern and Islamic Studies. Her dissertation is entitled "Arabic Cryptologic Treatises from the 9–14th Centuries." She is currently pursuing a Ph.D. in History and Middle Eastern Studies at Harvard University.

References

1. Allen, R. 1998. *The Arabic Literary Heritage: The Development of Its Genres and Criticisms*. Cambridge: The Cambridge University Press.
2. Amari, M. 1863–1867. *I Diplomi Arabi del R. Archivio Fiorentino*. Florence: Tip F. Le Monnier.
3. Al-'Anṣārī, 'U. I. 1961. *Tafriḡ Al-kurūb fī Tadbīr Al-ḡurūb*. Cairo: The American University at Cairo Press.
4. Atiya, A. S. 1966. "Egypt and Aragon: Embassies and Diplomatic Correspondence between 1300 and 1330 A.D.," *Abhandlungen für die Kunde Des Morgenlandes/ herausgegeben Von Der Deutschen Morgenländischen Gesellschaft*, 23(7):1–73.
5. Bailey, J. E. 1910. Cryptography. In *The Encyclopaedia Britannica*, 11th ed. New York: The Encyclopaedia Britannica Company.
6. Bohak, G. 2008. *The Jewish Magical Texts from the Cairo Genizah*. University of Cambridge Centre for Modern Hebrew Studies Lecture. Cambridge, UK: Faculty of Asian & Middle Eastern Studies.
7. Bosworth, C. E. 1963. "The Section on Codes and their Decipherment in Qalqashandi's Subh Al-A'ṣha," *Journal of Semitic Studies*, 8(1):17–33.
8. Carter, M. G. 1990. Arabic Lexicography. In *The Cambridge History of Arabic Literature: Religions, Learning and Science in the 'Abbāsīd period*, edited by M. J. L. Young, J. D. Latham, and R. B. Serjeant. Cambridge: Cambridge University Press. pp. 106–117.
9. Coke, R. 1927. *Baghdad: The City of Peace*. London: Thornton Butterworth Ltd.
10. Fikry, S. A. 1966. *Postal History of Egypt to 1900*. London: The Royal Philatelic Society.
11. Goodman, L. E. 1990. The Translation of Greek Materials into Arabic. In *The Cambridge History of Arabic Literature: Religions, Learning and Science in the 'Abbāsīd Period*, edited by M. J. L. Young, J. D. Latham, and R. B. Serjeant. Cambridge: Cambridge University Press, pp. 377–397.
12. Gottschalk, H. L. 1960–2005. *Dīwān: Egypt*. In *The Encyclopaedia of Islam*, edited by P. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel, and W. P. Heinrichs. 2nd ed. 11 vols. Leiden: E. J. Brill.
13. Hill, D. R. 1990. Mathematics and Applied Science. In *The Cambridge History of Arabic Literature: Religions, Learning and Science in the 'Abbāsīd Period*, edited by M. J. L. Young, J. D. Latham, and R. B. Serjeant. Cambridge: Cambridge University Press, pp. 248–273.

14. Holt, P. M., A. Lambton, and B. Lewis, eds. 1970. *The Cambridge History of Islam: Islamic Society and Civilization*, Vol 2b. London: Cambridge University Press.
15. Humphreys, R. S. 1977. "The Emergence of the Mamlūk Army," *Studia Islamica*, 45:67–99.
16. Ibn Dunaynīr, I. 2005. "Maqāṣid al-fuṣūl al-mutarġima ‘an ḥall at-targama." In *Arabic Origins of Cryptology*, edited by Mrāyātī, Muḥammad, Yaḥyá Mīr ‘Alam, Muḥammad Ḥassān al-Ṭayyān. Vol. 4. Riyadh: KFCRIS & KACST, pp. 61–189.
17. Ibn Khaldūn, A. 1978. *al-Muqaddima li-ibn Khaldūn*. Beirut: Dār al-Qalām.
18. Al-Kadī, I. A. 1992. "Origins of Cryptology: The Arab Contributions," *Cryptologia*, 16(2):97–126.
19. Kahn, D. 1967. *The Codebreakers: The Story of Secret Writing*. New York: Macmillan.
20. Kahn, D. Interview. 4 January 2008.
21. Al-Kindī, Y. 2003. Risāla fī ‘istikhrāġ al-mu‘ammā. In *Arabic Origins of Cryptology*, edited by Mrāyātī, Muḥammad, Yaḥyá Mīr ‘Alam, Muḥammad Ḥassān al-Ṭayyān. Vol. 1. Riyadh: KFCRIS & KACST, pp. 107–203.
22. Kunitzsch, P. 2003. The Transmission of Hindu-Arabic Numerals Reconsidered. In *The Enterprise of Science in Islam: New Perspectives*, edited by J. Hogendijk and Abdelhamid Sabra. Massachusetts: The MIT Press, pp. 3–21.
23. Lichtenstadter, I. 1976. *Introduction to Classical Arabic Literature: With Selections from Representative Works in English Translation*. New York: Schocken Books.
24. "Al-Maqāla al-ūlā." 2005. *Arabic Origins of Cryptology*, edited by Mrāyātī, Muḥammad, Yaḥyá Mīr ‘Alam, Muḥammad Ḥassān al-Ṭayyān. Vol. 6. Riyadh: KFCRIS & KACST, pp. 27–55.
25. Massey, J. L. 2008. "Review of Series on Arabic Origins of Cryptology," *Cryptologia*, 32(3):280–283.
26. Mez, A. 1979. *The Renaissance of Islam*. Trans. Salahuddin Khuda Bakhsh and D.S. Margoliouth. India: Idarah-i Adabiyat-i Delli.
27. Mrāyātī, Muḥammad, Yaḥyá Mīr ‘Alam, Muḥammad Ḥassān al-Ṭayyān, eds. 2004. *Arabic Origins of Cryptology*. Riyadh: KFCRIS & KACST, 6 vols.
28. Rashed, R. 1960–2005. al-Riyādiyyāt. In *The Encyclopaedia of Islam*, edited by P. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel, and W. P. Heinrichs. 2nd ed. 11 vols. Leiden: E. J. Brill.
29. "Risāla fī istikhrāġ al-mu‘ammā min aš-šī‘r." 2005. In *Arabic Origins of Cryptology*, edited by Mrayati, Muḥammad, Yaḥyá Mīr ‘Alam, Muḥammad Ḥassān al-Ṭayyān. Vol. 5. Riyadh: KFCRIS & KACST, pp. 63–117.
30. Sauvaget, J. 1941. *La Poste aux Chevaux dans l'Empire des Mamelouks*. Paris: Adrien-Maisonneuve.
31. Scanlon, G. T., ed. and trans. 1961. *A Muslim Manual of War*. Cairo: The American University at Cairo Press.
32. Sourdel, D. 1960–2005. al-Barāmika. In *The Encyclopaedia of Islam*, edited by P. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel, and W. P. Heinrichs. 2nd ed. 11 vols. Leiden: E. J. Brill.
33. Versteegh, K. 2001. *The Arabic Language*. Edinburgh: Edinburgh University Press.
34. Villiers, A. 1968. *Sons of Sinbad: An Account of Sailing with the Arabs in Their Dhows, in the Red Sea, Around the Coasts of Arabia, and to Zanzibar and Tanganyika: Pearlning in the Persian Gulf: And the Life of the Shipmasters, the Mariners and Merchants of Kuwait*. New York: Charles Scribner's Sons.
35. Wüstenfeld, F. 1879. "Eine Arabische Geheimschrift," *Nachrichten*, 15:349–355.