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Robert Mahler

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The testimony of the Islamic cemetery on Kom el-Dikka

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REFERENCES

Abbreviations

AJPA	*American Journal of Physical Anthropology*
ASAE	*Annales du Service des Antiquités de l'Égypte*
BSAA	*Bulletin de la Société archéologique d'Alexandrie*
EtTrav	*Études et travaux*
PAM	*Polish Archaeology in the Mediterranean*

Abulafia, D. (2014). *The Great Sea: A human history of the Mediterranean*. London: Penguin Books

Acsádi, G. and Nemeskéri, J. (1970). *History of human life span and mortality*. Budapest: Akadémiai Kiadó

Adriani, A. (1940). *Annuaire du Musée gréco-romain d'Alexandrie, 1935–1939*. Alexandria: Société de publications égyptiennes

Agarwal, S.C. and Glencross, B.A. (2011). Building a social bioarchaeology. In S.C. Agarwal and B.A. Glencross (eds), *Social bioarchaeology* (pp. 1–11). Chichester: Wiley-Blackwell

Alt, K.W. (1997). *Odontologische Verwandtschaftsanalyse: Individuelle Charakteristika der Zähne in ihrer Bedeutung für Anthropologie, Archäologie und Rechtsmedizin*. Stuttgart: G. Fischer

Alt, K.W., Rösing, F.W., and Teschler-Nicola, M. (eds). (1998). *Dental anthropology: Fundamentals, limits and prospects*. Vienna: Springer

Alt, K.W. and Türp, J.C. (1998). Roll call: Thirty-two white horses on a red field. The advantages of the FDI two-digit system of designating teeth. In K.W. Alt, F.W. Rösing, and M. Teschler-Nicola (eds), *Dental anthropology: Fundamentals, limits and prospects* (pp. 41–55). Vienna: Springer

Ambraseys, N. (2006). Earthquakes and archaeology. *Journal of Archaeological Science*, 33, 1008–1016

Anderson, M.F., Anderson, D.T., and Wescott, D.J. (2010). Estimation of adult skeletal age-at-death using the Sugeno fuzzy integral. *AJPA*, 142(1), 30–41

Arbel, Y. (2017). Post-medieval Muslim burials in Jaffa: Archaeological evidence and historical perspective. *Journal of Islamic Archaeology*, 4(1), 87–112

Aufderheide, A.C. and Rodriguez-Martin, C. (1998). *The Cambridge encyclopedia of human paleopathology*. Cambridge: Cambridge University Press

Austin, A.E. (2011). Preliminary remarks on the Coptic burials at Karanis. *Coptica*, 10, 45–60

Badawy, A. (1999). Historical seismicity of Egypt. *Acta Geodaetica et Geophysica Hungarica*, 34(1–2), 119–135. http://dx.doi.org/10.1007/BF03325564

Bagnall, R.S. and Frier, B.W. (1994). *The demography of Roman Egypt* (=*Cambridge Studies in Population, Economy, and Society in Past Time* 23). Cambridge: Cambridge University Press

Bass, W.M. (1995). *Human osteology: A laboratory and field manual* (=*Missouri Archaeological Society Special Publications* 2) (4th ed.). Columbia, MO: Missouri Archaeological Society

Bianquis, T. (1998). Autonomous Egypt from Ibn Tulun to Kafur, 868–969. In C.F. Petry (ed.), *The Cambridge history of Egypt* I. *Islamic Egypt, 640–1517* (pp. 86–119). Cambridge: Cambridge University Press

Björnesjö, S. and Speiser, P. (2014). The South Necropolis of the Fatimid Cemetery of Aswan. *Annales Islamologiques*, 48(2), 117–134

Borkowska-Kołątaj, T. and Kołątaj, W. (1972). Identification et localisation des galeries de Hogarth sur le terrain de Kom el-Dikka (Alexandrie). *EtTrav*, 6, 169–172

Bramoullé, D. (2011). Alexandrie, les Fatimides et la mer (969–1171). In C. Décobert, J.-Y. Empereur, and C. Picard (eds), *Alexandrie médiévale 4* (=*Études alexandrines* 24) (pp. 83–107). Alexandria: Centre d'études alexandrines

Breccia, E. (1932). *Le Musée gréco-romain, 1925–1931*. Bergamo: Instituto Italiano d'Arti Grafiche

Brickley, M. and McKinley, J.I. (eds). (2004). *Guidelines to the standards for recording human remains* (=*Institute of Field Archaeologists Paper* 7). Southampton–Reading: BABAO, Department of Archaeology, University of Southampton; Institute of Field Archaeologists

Brooks, S. and Suchey, J.M. (1990). Skeletal age determination based on the *os pubis*: A comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. *Human Evolution*, 5(3), 227–238

Brothwell, D.R. (1981). *Digging up bones: The excavation, treatment, and study of human skeletal remains* (3rd ed.). Ithaca, NY: Cornell University Press

Buikstra, J.E. and Ubelaker, D.H. (eds). (1994). *Standards for data collection from human skeletal remains: Proceedings of a seminar at the Field Museum of Natural History, organized by Jonathan Haas* (=*Arkansas Archeological Survey Research Series* 44). Fayetteville, AR: Arkansas Archeological Survey

Butler, A.J. (1902). *The Arab conquest of Egypt and the last thirty years of the Roman dominion*. Oxford: Clarendon Press

Cannon, A. and Cook, K. (2015). Infant death and the archaeology of grief. *Cambridge Archaeological Journal*, 25(2), 399–416

Caselitz, P. (1998). Caries – ancient plague of humankind. In K.W. Alt, F.W. Rösing, and M. Teschler-Nicola (eds), *Dental anthropology: Fundamentals, limits and prospects* (pp. 203–226). Vienna: Springer

Cashmore, L. and Zakrzewski, S.R. (2009). The expression of asymmetry in hand bones from the medieval cemetery at Écija, Spain. In M.E. Lewis and M. Clegg (eds), *Proceedings of the Ninth Annual Conference of the British Association for Biological Anthropology and Osteoarchaeology, Department of Archaeology, University of Reading 2007* (pp. 79–92), Oxford: Archaeopress

Chamberlain, A. (2006). *Demography in archaeology*. Cambridge: Cambridge University Press

Combe, E. (1936). Inscriptions arabes du Musée d'Alexandrie. *BSAA*, 30, 56–78

Cox, M. (2000). Ageing adults from the skeleton. In M. Cox and S. Mays (eds), *Human osteology in archaeology and forensic science* (pp. 61–81). London: Greenwich Medical Media

Dąbrowski, L. (1960). Résumé des recherches archéologiques faites autour du Fort Kôm el-Dikka en Alexandrie. *Bulletin de Faculté des Lettres, Université d'Alexandrie*, 14, 39–49

Dąbrowski, L. (1966). Two Arab necroples [*sic*] discovered at Kom el-Dikka, Alexandria. *EtTrav*, 1, 171–180

Delia, D. (1988). The population of Roman Alexandria. *Transactions of the American Philological Association*, 118, 275–292

Drennan, R.D. (2009). *Statistics for archaeologists: A commonsense approach* (2nd ed.). Dodrecht: Springer

Duyar, İ. and Erdal, Y.S. (2003). A new approach for calibrating dental caries frequency of skeletal remains. *HOMO: Journal of Comparative Human Biology*, 54(1), 57–70

Dzierżykray-Rogalski, T. (1962). Sprawozdanie z wstępnych badań kości ludzkich z dwóch nekropolii arabskich w Aleksandrii (Report on the preliminary examination of human bones from two Arab necropolises in Alexandria). *Człowiek w Czasie i Przestrzeni*, 5(2), 83–88 (in Polish)

Dzierżykray-Rogalski, T. (1963). Wstępne badania kości ludzkich z Kom el-Dikka w Aleksandrii (Preliminary investigations of human bones from Kom el-Dikka in Alexandria). *Sprawozdania z Prac Naukowych Wydziału Nauk Społecznych*, 5, 85–90 (in Polish)

Dzierżykray-Rogalski, T. (1966a). An anatomical and anthropological analysis of human skeletal remains from the Arab necroples [*sic*] at Kom el Dikka, Alexandria (Egypt). *EtTrav*, 1, 201–216

Dzierżykray-Rogalski, T. (1966b). Compte-rendu de l'examen anthropologique des ossements humains trouvés dans les necropoles arabes de Kom El-Dikka à Alexandrie. *ASAE*, 59, 193–203

Dzierżykray-Rogalski, T. (1968). Human bones from trench F and G of the Moslem necroples [*sic*] at Kom el-Dikka, Alexandria (Egypt). *EtTrav*, 2, 229–242

Dzierżykray-Rogalski, T. (1969). Notices concerning the common graves from the Moslem necropolis at Kom el-Dikka in Alexandria (Egypt). *Africana Bulletin*, 11, 102–107

Dzierżykray-Rogalski, T. (1977). Zagadnienia paleopatologii w nekropolach muzułmańskich na Kom el-Dikka (Issues of palaeopathology in Muslim necropolises in Kom el-Dikka). In *Starożytna Aleksandria w badaniach polskich: Materiały Sesji Naukowej zorganizowanej przez Instytut Archeologii Uniwersytetu Jagiellońskiego, Kraków, 8–9 kwietnia 1975 r.* (pp. 211–216). Warsaw: Państwowe Wydawnictwo Naukowe (in Polish)

Dzierżykray-Rogalski, T. and Promińska, E. (1968). Studies on human bones from sector M-IX of the Moslem necroples [*sic*] at Kom el-Dikka, Alexandria (Egypt). *EtTrav*, 2, 173–228

Dzierżykray-Rogalski, T. and Promińska, E. (1970). Further studies of human bones from the Moslem necropoles at Kom el-Dikka, Alexandria, Egypt. *EtTrav*, 4, 137–214

Dzierżykray-Rogalski, T. and Promińska, E. (1971). Studies of human bones from the Moslem necropoles overlying the Roman theatre at Kom el Dikka in Alexandria. *EtTrav*, 5, 151–192

Dzierżykray-Rogalski, T. and Promińska, E. (1985). Sur la paléopathologie dans Alexandrie musulmane. In P. Posener-Kriéger (ed.), *Mélanges Gamal Eddin Mokhtar* II (=*Bibliothèque d'étude* 97/2) (pp. 243–247). Cairo: Institut français d'archéologie orientale

Dzierżykray-Rogalski, T. and Promińska, E. (1992). Anthropological and paleopathological researches – the Polish Centre of Mediterranean Archaeology of Warsaw University. In S. Jakobielski and J. Karkowski (eds), *50 years of Polish excavations in Egypt and the Near East: Acts of the Symposium at the Warsaw University 1986* (pp. 91–95). Warsaw: Centre d'archéologie méditerranéenne de l'Académie polonaise des sciences

Dzierżykray-Rogalski, T., Promińska, E., and Rodziewicz, M. (1972). Refuse of animal bones from Kôm el-Dikka, Alexandria. *EtTrav*, 6, 173–178

Eakins, J.K. (1993). *Tell El-Hesi: the Muslim cemetery in Fields V and VI/IX (Stratum II).* Winona Lake Ind.: Eisenbrauns

Feldesman, M.R. and Fountain, R.L. (1996). "Race" specificity and the femur/stature ratio. *AJPA*, 100(2), 207–224

Foss, C. (2009). Egypt under Muʿāwiya part II: Middle Egypt, Fusṭāṭ and Alexandria. *Bulletin of the School of Oriental and African Studies*, 72(2), 259–278

Francis Jr, P. (1989). Beads of the early Islamic period. *Beads: Journal of the Society of Bead Researchers*, 1, 21–39

Fraser, P.M. (1991). Alexandria, Christian and medieval. In A.S. Atiya (ed.), *The Coptic encyclopedia* I (pp. 88–92). New York: Macmillan

Fraser, P.M. (1993). Byzantine Alexandria: Decline and fall. *BSAA*, 45, 91–105

Frayer, D.W. and Wolpoff, M.H. (1985). Sexual dimorphism. *Annual Review of Anthropology*, 14(1), 429–473

Freestone, I.C. (2006). Glass production in Late Antiquity and the Early Islamic period: a geochemical perspective. *Geological Society, London, Special Publications*, 257, 201–216

Frenkel, M. (2014). Medieval Alexandria – life in a port city. *Al-Masāq: Journal of the Medieval Mediterranean*, 26(1), 5–35

Frenkel, Y. (2014). Alexandria in the ninth/fifteenth century: A Mediterranean port city and a Mamlūk prison city. *Al-Masāq: Journal of the Medieval Mediterranean*, 26(1), 78–92

Fully, G. (1956). Une nouvelle méthode de détermination de la taille. *Annales de médecine légale, de criminologie et de police scientifique*, 36, 266–273

Fully, G. and Pineau, H. (1960). Détermination de la stature au moyen du squelette. *Annales de médecine légale, de criminologie et de police scientifique*, 40, 145–154

Gascoigne, A. (2002). *The impact of the Arab conquest on Late Roman settlement in Egypt* (unpubl. Ph.D. diss.). University of Cambridge

Giannecchini, M. and Moggi-Cecchi, J. (2008). Stature in archeological samples from central Italy: Methodological issues and diachronic changes. *AJPA*, 135(3), 284–292

Godlewski, W. (2011). Naqlun cemeteries. In G.A. Belova and S.V. Ivanov (eds), *Achievements and problems of modern Egyptology: Proceedings of the International Conference held in Moscow on September 29–October 2, 2009* (pp. 138–151). Moscow: Russian Academy of Sciences

Goodman, A.H. and Martin, D.L. (2002). Reconstructing health profiles from skeletal remains. In R.H. Steckel and J.C. Rose (eds), *The backbone of history: Health and nutrition in the Western Hemisphere* (pp. 11–60). Cambridge: Cambridge University Press

Goodman, A.H. and Rose, J.C. (1991). Dental enamel hypoplasias as indicators of nutritional status. In M.A. Kelley and C.S. Larsen (eds), *Advances in dental anthropology* (pp. 279–293). New York: Wiley-Liss

Gorzalczany, A. (2007). The Kefar Saba cemetery and differences in orientation of Late Islamic burials from Israel/Palestine. *Levant*, 39(1), 71–79

Gorzalczany, A. (2016). A Mamluk-period settlement and cemetery at Ge'alya, near Yavne. *'Atiqot*, 86, 69–110

Gourinard, H. (2012). "Alexandrie, ville sous haute surveillance." Voyage et espionnage aux XIV[e]–XV[e] siècles, d'après les récits de voyageurs et de pèlerins occidentaux. In K. Petkov and R. Blumenfeld-Kosinski (eds), *Philippe de Mézières and His Age* (pp. 427–450). Leiden: Brill

Gralla, G. (1964). Długość szkieletu *in situ* a wzrost wyliczony z kości długich (Skeleton length *in situ* and height calculated from long bones). *Materiały i Prace Antropologiczne*, 65, 241–268 (in Polish)

Haas, C. (1997). *Alexandria in late antiquity: Topography and social conflict*. Baltimore, MD: Johns Hopkins University Press

Halevi, L. (2007). *Rites for the dead: Funerals and the afterlife in early Islam*. Cairo: American University in Cairo Press

Helman, C.G. (2007). *Culture, health and illness* (5th ed.). London: Hodder Arnold

Hillson, S. (1996). *Dental anthropology*. Cambridge: Cambridge University Press

Hogarth, D.G. and Benson, E.F. (1894–1895). Report on prospects of research in Alexandria. *Archaeological Report (Egypt Exploration Fund)*, 1–33

Howell, D. (2012). *Statistical methods for psychology* (8th ed.). Belmont, CA: Wadsworth

Inskip, S., Carroll, G., Waters-Rist, A., and López-Costas, O. (2019). Diet and food strategies in a southern al-Andalusian urban environment during Caliphal period, Écija, Sevilla. *Archaeological and Anthropological Sciences*, 11, 3857–3874

Insoll, T. (1999). *The archaeology of Islam*. Oxford: Blackwell

Isma'il, M.H. al-Din. (1993). The fortifications of Alexandria during the Islamic period. *BSAA*, 45, 153–161

Jackes, M. (1993). On paradox and osteology. *Current Anthropology*, 34(4), 434–439

Jackes, M. (2011). Representativeness and bias in archaeological skeletal samples. In S.C. Agarwal and B.A. Glencross (eds), *Social bioarchaeology* (pp. 107–146). Chichester: Wiley-Blackwell

Jantz, R.L., Hunt, D.R., and Meadows, L. (1994). Maximum length of the tibia: How did Trotter measure it? *AJPA*, 93(4), 525–528

Johnson, M. (2010). *Archaeological theory: An introduction* (2nd ed.). Chichester: Wiley-Blackwell

Kaegi, W.E. (1998). Egypt on the eve of the Muslim conquest. In C.F. Petry (ed.), *The Cambridge history of Egypt* I. *Islamic Egypt, 640–1517* (pp. 34–61). Cambridge: Cambridge University Press

Keilman, N. (2010). On age structures and mortality. In S. Tuljapurkar, N. Ogawa, and A.H. Gauthier (eds), *Ageing in advanced industrial states* (pp. 23–46). Heidelberg–New York: Springer

Kennedy, H. (1981). Central government and provincial élites in the early 'Abbāsid caliphate. *Bulletin of the School of Oriental and African Studies*, 44(1), 26–38

Kennedy, H. (1998). Egypt as a province in the Islamic caliphate, 641–868. In C.F. Petry (ed.), *The Cambridge history of Egypt* I. *Islamic Egypt, 640–1517* (pp. 62–85). Cambridge: Cambridge University Press

Kennedy, H. (2011). *Wielkie arabskie podboje: jak ekspansja islamu zmieniła świat* (*The great Arab conquests: How the spread of Islam changed the world we live in*) (M. Wilk, trans.). Warsaw: Wydawnictwo Naukowe PWN (in Polish)

Klaus, H.D. (2017). Paleopathological rigor and differential diagnosis: Case studies involving terminology, description, and diagnostic frameworks for scurvy in skeletal remains. *International Journal of Paleopathology*, 19, 96–110

Kołątaj, W. (1976). La dernière période d'utilisation et la destruction des thermes romains tardifs à Kôm el-Dikka. *EtTrav*, 9, 217–229

Kołątaj, W. and Kołątaj, T. (1975). Polish excavations at Kom el-Dikka in Alexandria 1967. Report on the reconstruction of the "theatre." *BSAA*, 43, 79–97

Kowalska, M. (1970). Quatre fragments de stèles funéraires arabes de Kôm el-Dikka. *EtTrav*, 4, 133–136

Kozak, J. (1996). Stature reconstruction from long bones. The estimation of the usefulness of some selected methods for skeletal populations from Poland. *Variability and Evolution*, 5, 83–94

Kozak, J. and Krenz-Niedbała, M. (2002). The occurrence of cribra orbitalia and its association with enamel hypoplasia in a medieval population from Kołobrzeg, Poland. *Variability and Evolution*, 10, 75–82

Kubiak, W. (1965). *Archeologia muzułmańskiej Aleksandrii do okresu wypraw krzyżowych* (Archeology of Muslim Alexandria to the Crusades) (unpubl. Ph.D. diss.). University of Warsaw (in Polish)

Kubiak, W. (1967a). Les fouilles polonaises à Kôm el Dick en 1963 et 1964. *BSAA*, 42, 47–80

Kubiak, W. (1967b). Stèles funéraires arabes de Kom el-Dick. *BSAA*, 42, 17–26

Kubiak, W. (1969). Overseas pottery trade of mediaeval Alexandria as shown by recent archaeological discoveries. A preliminary communication. *Folia Orientalia*, 10, 5–30

Kubiak, W. (1975). Inscriptions arabes de Kom el Dick, IIe partie. *BSAA*, 43, 133–140

Kubiak, W. (1987). *Al-Fusṭāṭ: Its foundation and early urban development*. Cairo: American University in Cairo Press

Kubiak, W. (1998). Nowe badania w Aleksandrii w zakresie archeologii islamu: Szkic (New research in Alexandria on Islamic archaeology). *Światowit*, 41 Fasc. A, 15–25 (in Polish)

Kubiak, W. and Makowiecka, E. (1973). Polish excavations at Kom el-Dikka in 1965 and 1966 (preliminary report). *ASAE*, 61, 93–124

Kucharczyk, R. (2012). Aleksandria. Opowieść o mieście (Alexandria. The story of the city). In *Starożytna Aleksandria. 50 lat polskich badań archeologicznych i prac konserwatorskich na Kom el-Dikka* (pp. 9–53). Warsaw: PCMA UW (in Polish)

Kucharczyk, R. (2015). Islamic glass from sector U (2012–2013). *PAM*, 24/1, 73–86

Kulicka, E. (2007). The Moslem cemeteries on Kom el-Dikka in Alexandria. Excavation season 2004/2005. *PAM*, 17, 35–39

Kulicka, E. (2008). Moslem cemetery in Areas CW and L on Kom el-Dikka (excavations in the 2005/2006 season), appendix to: G. Majcherek, Kom el-Dikka. Excavation and preservation work, 2005/2006. *PAM*, 18, 45–50

Kulicka, E. (2010). The Islamic graveyard on Kom el-Dikka in Alexandria. Excavations in the 2006/2007 field season. *PAM*, 19, 49–55

Kulicka, E. (2011). Remarks on the typology of Islamic graves from the cemeteries on Kom el-Dikka in Alexandria. *PAM*, 20, 483–498

Kulicka, E. (2015). Islamic necropolis at Kom el-Dikka in Alexandria: Research in the 2010–2013 seasons. *PAM*, 24/1, 62–72

Kulicka, E. (2016). Islamic cemetery at Kom el-Dikka in Alexandria: Research in the 2014 and 2015 excavation seasons, appendix to: G. Majcherek, Alexandria, Kom-el-Dikka. Seasons 2014–2015. *PAM*, 25, 53–62

Lane, A. (1949). Archaeological excavation at Kom el Dik: A preliminary report on the medieval pottery. *Bulletin of the Faculty of Arts, Farouk I University, Alexandria*, 5, 143–147

Lane-Poole, S. (1901). *A history of Egypt* VI. *In the Middle Ages*. London: Methuen

Lanfranco, L.P. and Eggers, S. (2010). The usefulness of caries frequency, depth, and location in determining cariogenicity and past subsistence: A test on early and later agriculturalists from the Peruvian coast. *AJPA*, 143(1), 75–91

Lanfranco, L.P. and Eggers, S. (2012). Caries through time: An anthropological overview. In Ming-Yu Li (ed.), *Contemporary approach to dental caries* (pp. 3–34). Retrieved from https://www.intechopen.com/books/contemporary-approach-to-dental-caries/caries-archaeological-and-historical-record (accessed: 28.03.2020)

Larsen, C.S. (1997). *Bioarchaeology: Interpreting behavior from the human skeleton* (=*Cambridge Studies in Biological Anthropology* 21). Cambridge: Cambridge University Press

Leisten, T. (1990). Between orthodoxy and exegesis: Some aspects of attitudes in the shariʿa toward funerary architecture. *Muqarnas*, 7, 12–22

Lewartowski, K. (2001). Archeologia śmierci: Stan i potencjał (Archaeology of death: State and potential). *Światowit*, 3 (44) Fasc. B, 133–144 (in Polish)

Lewis, M.E. (2007). *The bioarchaeology of children: Perspectives from biological and forensic anthropology* (=*Cambridge Studies in Biological and Evolutionary Anthropology* 50). Cambridge: Cambridge University Press

Lingström, P. and Borrman, H. (1999). Distribution of dental caries in an early 17th century Swedish population with special reference to diet. *International Journal of Osteoarchaeology*, 9(6), 395–403

Lipińska, J. (1966). Polish excavations at Kom el Dikka in Alexandria. *EtTrav*, 1, 181–198

Lipińska, J. and Riad, H. (1966). Trial pits at Kom el-Dikka in Alexandria. *ASAE*, 59, 99–108

Little, L.K. (2006). Life and afterlife of the first plague pandemic. In L.K. Little (ed.), *Plague and the end of Antiquity: The pandemic of 541–750* (pp. 3–32). Cambridge: Cambridge University Press

Lorkiewicz, W. (2012). *Biologia wczesnorolniczych populacji ludzkich grupy brzesko-kujawskiej kultury lendzielskiej (4600–4000 BC)* (Biology of early agricultural human populations of the Brześć Kujawski Group of the Lengyel Culture [4600–4000 BC]). Łódź: Wydawnictwo Uniwersytetu Łódzkiego (in Polish)

Lorkiewicz, W. and Śmiszkiewicz-Skwarska, A. (2003). Dymorfizm płciowy szkieletu kończyn w populacjach ludzkich wczesnohistorycznych i nowożytnych z Brześcia Kujawskiego (Sexual dimorphism of the limbs in the early-historical and modern human populations of Brześć Kujawski). In W. Dzieduszycki and J. Wrzesiński (eds), *Kobieta, śmierć, mężczyzna. Funeralia Lednickie – spotkanie 5* (pp. 219–224). Poznań: Stowarzyszenie Naukowe Archeologów Polskich, Oddział w Poznaniu (in Polish)

Lovejoy, C.O. (1985). Dental wear in the Libben population: Its functional pattern and role in the determination of adult skeletal age at death. *AJPA*, 68(1), 47–56

Lovejoy, C.O., Meindl, R.S., Mensforth, R.P., and Barton, T.J. (1985). Multifactorial determination of skeletal age at death: A method and blind tests of its accuracy. *AJPA*, 68(1), 1–14

Lovejoy, C.O., Meindl, R.S., Pryzbeck, T.R., and Mensforth, R.P. (1985). Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of adult skeletal age at death. *AJPA*, 68(1), 15–28

Lovell, N.C. (1997). Trauma analysis in paleopathology. *AJPA*, 104(S25), 139–170

Lucidchart. (n.d.). *What is an entity relationship diagram (ERD)?* Retrieved from https://www.lucidchart.com/pages/er-diagrams (accessed: 28.03.2020)

Lukacs, J.R. and Largaespada, L.L. (2006). Explaining sex differences in dental caries prevalence: Saliva, hormones, and "life-history" etiologies. *American Journal of Human Biology*, 18(4), 540–555

Macklin, P.A. (2004). *The excavations, interpretation and analysis of the Muslim necropolis at Quseir al-Qadim, Red Sea coast, Egypt* (unpubl. Ph.D. diss.). University of Southampton

Mahler, R. (2007). Analysis of skeletal material from the Kom el-Dikka site, 2004/2005 season. *PAM*, 17, 40–44

Mahler, R. (2012). Kom el-Dikka 2005–2009: Selected anthropological research. *PAM*, 21, 49–58

Mahler, R. and Okularczyk, U. (2016). Kom el-Dikka 2014: Human bones from Area U. *PAM*, 25, 64–86

Mahmoud Bey. (1872). *Mémoire sur l'antique Alexandrie, ses faubourgs et environs découverts, par les fouilles sondages, nivellements et autres recherches, faits d'après les ordres de son Altesse, Ismaïl Pacha*. Copenhagen: Luno

Mair, P. and Wilcox, R. (2019). Robust statistical methods in R using the WRS2 package. *Behavior Research Methods*, 52(2), 464–488. https://doi.org/10.3758/s13428-019-01246-w

Majcherek, G. (2007a). Kom el-Dikka. Excavation and preservation work. Preliminary report, 2004/2005. *PAM*, 17, 21–34

Majcherek, G. (2007b). The late Roman auditoria of Alexandria: An archaeological overview. In T. Derda, T. Markiewicz, and E. Wipszycka (eds), *Alexandria: Auditoria of Kom el-Dikka and late antique education* (=*Journal of Juristic Papyrology Supplement* 8) (pp. 11–50). Warsaw: Raphael Taubenschlag Foundation

Majcherek, G. (2010). The auditoria on Kom el-Dikka. A glimpse of late antique education in Alexandria. In T. Gagos and A. Hyatt (eds), *Proceedings of the 25th International Congress of Papyrology, Ann Arbor, July 29–August 4, 2007* (pp. 471–484). Ann Arbor, MI: University of Michigan Library, Scholarly Publishing Office

Majcherek, G. and Kucharczyk, R. (2014). Alexandria. Excavations and preservation work on Kom el-Dikka. Season 2011. *PAM*, 23/1, 23–44

Malinowski, A. and Bożiłow, W. (1997). *Podstawy antropometrii: Metody, techniki, normy* (The basics of anthropometry: Methods, techniques, norms). Warsaw: Wydawnictwo Naukowe PWN (in Polish)

Manouvrier, L. (1892). Détermination de la taille d'après les grands os des membres. *Revue mensuelle de l'École d'anthropologie de Paris*, 2, 227–233

Marco, S. (2008). Recognition of earthquake-related damage in archaeological sites: Examples from the Dead Sea fault zone. *Tectonophysics*, 453, 148–156

Martin, D.L., Harrod, R.P., and Pérez, V.R. (2013). *Bioarchaeology: An integrated approach to working with human remains*. New York: Springer

Martin, R. and Saller, K. (eds). (1959). *Lehrbuch der Anthropologie: In systematischer Darstellung mit besonderer Berücksichtigung der anthropologischen Methoden* II (3rd ed.). Stuttgart: G. Fischer

McIlvaine, B.K. (2015). Implications of reappraising the iron-deficiency anemia hypothesis. *International Journal of Osteoarchaeology*, 25(6), 997–1000

McKenzie, J.S. (2007). The place in late antique Alexandria "where alchemists and scholars sit (…) was like stairs." In T. Derda, T. Markiewicz, and E. Wipszycka (eds), *Alexandria: Auditoria of Kom el-Dikka and late antique education* (=*Journal of Juristic Papyrology Supplement* 8) (pp. 53–83). Warsaw: Raphael Taubenschlag Foundation

Meindl, R.S. and Lovejoy, C.O. (1989). Age changes in the pelvis: Implications for paleodemography. In M.Y. Işcan (ed.), *Age markers in the human skeleton* (pp. 137–168). Springfield, IL: C.C. Thomas

Meyza, H. (2000). Sector G: Stratigraphy of the Arab necropolis. In Z. Kiss, G. Majcherek, H. Meyza, H. Rysiewski, and B. Tkaczow, *Fouilles polonaises à Kôm el-Dikka (1986–1987)* (=*Alexandrie* 7) (pp. 35–80). Warsaw: Centre d'archéologie méditerranéenne de l'Académie polonaise des sciences

Mikhail, M.S.A. (2014). *From Byzantine to Islamic Egypt: Religion, identity and politics after the Arab conquest*. London–New York: I.B. Tauris

Moreda Blanco, F.J. and Serrano Noriega, R. (2008). Excavación arqueológica en el cementerio de rito islámico de San Nicolás. Ávila (mayo–junio de 2002). *Oppidum*, 4, 185–212

Ortner, D.J. (2003). *Identification of pathological conditions in human skeletal remains* (2nd ed.). San Diego, CA: Academic Press

Oxenham, M.F. and Cavill, I. (2010). Porotic hyperostosis and cribra orbitalia: The erythropoietic response to iron-deficiency anaemia. *Anthropological Science*, 118(3), 199–200

Pearson, K. (1899). Mathematical contributions to the theory of evolution. V. On the reconstruction of the stature of Prehistoric races. *Philosophical Transactions of the Royal Society of London. Series A, Containing Papers of a Mathematical or Physical Character*, 192, 169–244

Pearson, M.P. (1999). *The archaeology of death and burial*. College Station, TX: Texas A&M University Press

Petersen, A. (2013). The archaeology of death and burial in the Islamic world. In S. Tarlow and L. Nilsson Stutz (eds), *The Oxford handbook of the archaeology of death and burial* (pp. 241–258). Oxford: Oxford University Press

Petersen, H.C. (2005). On the accuracy of estimating living stature from skeletal length in the grave and by linear regression. *International Journal of Osteoarchaeology*, 15(2), 106–114

Petry, C.F. (ed.). (1998). *The Cambridge history of Egypt* I. *Islamic Egypt, 640–1517*. Cambridge: Cambridge University Press

Phenice, T.W. (1969). A newly developed visual method of sexing the os pubis. *AJPA*, 30(2), 297–301

Piasecki, E. (1975). Próba charakterystyki struktury wieku ludności z Kom el-Dikka w Aleksandrii w XIII–XIV w. Na podstawie danych o populacji szkieletowej (An attempt to characterise the age structure of the population of Kom el-Dikka in Alexandria in the 13th–14th century. Based on skeletal population data). *Materiały i Prace Antropologiczne*, 89, 117–146 (in Polish)

Piasecki, K. (1992). *Las nuevas escalas craneoscópicas: Observaciones preliminares*. Warsaw: Centro de Estudios Latinoamericanos, Universidad de Varsovia

Piontek, J. (1996). *Biologia populacji pradziejowych: zarys metodyczny* (Biology of prehistoric populations: Methodology) (2nd ed.). Poznań: Wydawnictwo Naukowe UAM (in Polish)

Piontek, J. (2003). Dymorfizm płciowy jako wyznacznik warunków życia w populacjach pradziejowych i historycznych (Sexual dimorphism as a determinant of living conditions in prehistoric and historical populations). In W. Dzieduszycki and J. Wrzesiński (eds), *Kobieta, śmierć, mężczyzna. Funeralia Lednickie – spotkanie 5* (pp. 59–64). Poznań: Stowarzyszenie Naukowe Archeologów Polskich, Oddział w Poznaniu (in Polish)

Pomeroy, E. and Zakrzewski, S.R. (2009). Sexual dimorphism in diaphyseal cross-sectional shape in the medieval Muslim population of Écija, Spain, and Anglo-Saxon Great Chesterford, UK. *International Journal of Osteoarchaeology*, 19, 50–65

Promińska, E. (1968). Un nouveau secteur de la nécropole arabe de Kôm el-Dikka à Alexandrie. *Africana Bulletin*, 9, 75–83

Promińska, E. (1972). *Investigations on the population of Muslim Alexandria: Anthropological-demographic study* (=*Travaux du Centre d'archéologie méditerranéenne de l'Académie polonaise des sciences* 12). Warsaw: Éditions scientifiques de Pologne

Promińska, E. (1980). Badania kości kończyn z nekropoli muzułmańskich w Aleksandrii (Testing of limb bones from Muslim necropoles in Alexandria). *Przegląd Antropologiczny*, 46(1), 3–20 (in Polish)

Promińska, E. (1985). *Variations de taille des habitants d'Alexandrie au cours des siècles* (=*Travaux du Centre d'archéologie méditerranéenne de l'Académie polonaise des sciences* 25). Warsaw: Éditions scientifiques de Pologne

Raxter, M.H., Auerbach, B.M., and Ruff, C.B. (2006). Revision of the Fully technique for estimating statures. *AJPA*, 130(3), 374–384

Raxter, M.H., Ruff, C.B., Azab, A., Erfan, M., Soliman, M., and El-Sawaf, A. (2008). Stature estimation in ancient Egyptians: A new technique based on anatomical reconstruction of stature. *AJPA*, 136(2), 147–155

Raymond, A. (2005). *Kair* (*Le Caire*) (P. Lewicka and K. Pachniak, trans.). Warsaw: Państwowy Instytut Wydawniczy (in Polish)

Redlak, M. (2011). Ornaments on funerary stelae of the 9th–12th centuries from Egypt – Josef Strzygowski's publication anew. *PAM*, 20, 561–574

Renfrew, C. and Bahn, P. (2008). *Archaeology: Theories, methods and practice* (5th ed.), London: Thames & Hudson

Rivera, F. and Mirazón Lahr, M. (2017). New evidence suggesting a dissociated etiology for cribra orbitalia and porotic hyperostosis. *AJPA*, 164(1), 76–96

Roberts, C.A. and Manchester, K. (2005). *The archaeology of disease* (3rd ed.). Ithaca, NY: Cornell University Press

Rodziewicz, M. (1978). Fouilles de sauvetage dans la partie Nord de Kôm el-Dikka. *EtTrav*, 10, 347–354

Rodziewicz, M. (1982). Graeco-Islamic elements at Kom el-Dikka in the light of new discoveries. Remarks on early medieval Alexandria. *Graeco-Arabica*, 1, 35–49

Rodziewicz, M. (1984). *Les habitations romaines tardives d'Alexandrie: À la lumière des fouilles polonaises à Kôm el-Dikka* (=*Alexandrie* 3). Warsaw: Éditions Scientifiques de Pologne

Rodziewicz, M. (1985). Excavations at Kom el-Dikka in Alexandria 1980–81 (preliminary report). *ASAE*, 70, 233–246

Rodziewicz, M. (1991). Excavations at Kom el-Dikka in 1980–1981. *BSAA*, 44, 71–83

Rodziewicz, M. (1998). Transformation of ancient Alexandria into a medieval city. In R.-P. Gayraud (ed.), *Colloque International d'Archéologie Islamique: IFAO, Le Caire, 3–7 février 1993* (pp. 369–386). Cairo: Institut français d'archéologie orientale

Rodziewicz, M. (2002). Mareotic harbours. In C. Décobert (ed.), *Alexandrie médiévale 2* (=*Études Alexandrines* 8) (pp. 1–22). Cairo: Institut français d'archéologie orientale

Rogers, J. and Waldron, T. (1995). *A field guide to joint disease in archaeology*. Chichester: J. Wiley

Rollet, É. (1888). *De la mensuration des os longs des membres dans ses rapports avec l'anthropologie, la clinique et la médecine judiciaire*. Lyon: A. Storck

Ronsmans, C., Graham, W.J., and Lancet Maternal Survival Series steering group. (2006). Maternal mortality: Who, when, where, and why. *Lancet*, 368(9542), 1189–1200

Ruff, C.B., Holt, B.M., Niskanen, M., Sladék, V., Berner, M., Garofalo, E., … Tompkins, D. (2012). Stature and body mass estimation from skeletal remains in the European Holocene. *AJPA*, 148(4), 601–617

Russell, J.C. (1966). The population of medieval Egypt. *Journal of the American Research Center in Egypt*, 5, 69–82

Ruxton, G.D. (2006). The unequal variance t-test is an underused alternative to Student's t-test and the Mann–Whitney U test. *Behavioral Ecology*, 17(4), 688–690

Rysiewski, H. (2000). Alexandria, Kom el-Dikka, sectors G and CS: Human skeletal remains from the multilayered Arabic necropolis explored in the years 1986 and 1987. In Z. Kiss, G. Majcherek, H. Meyza, H. Rysiewski, and B. Tkaczow, *Fouilles polonaises à Kôm el-Dikka (1986–1987)* (=*Alexandrie* 7) (pp. 99–129). Warsaw: Centre d'archéologie méditerranéenne de l'Académie polonaise des sciences

Rysiewski, H., Majcherek, G., and Meyza, H. (2000). Results of excavations of the western part of sector CS. In Z. Kiss, G. Majcherek, H. Meyza, H. Rysiewski, and B. Tkaczow, *Fouilles polonaises à Kôm el-Dikka (1986–1987)* (=*Alexandrie* 7) (pp. 81–98). Warsaw: Centre d'archéologie méditerranéenne de l'Académie polonaise des sciences

Sanders, P.A. (1998). The Fatimid state, 969–1171. In C.F. Petry (ed.), *The Cambridge history of Egypt* I. *Islamic Egypt, 640–1517* (pp. 151–174). Cambridge: Cambridge University Press

Saunders, N.J. (2007). *Alexander's tomb: Two thousand year obsession to find the lost conquerer*. Cairo: American University in Cairo Press

Saunders, S.R., De Vito, C., and Katzenberg, M.A. (1997). Dental caries in nineteenth century Upper Canada. *AJPA*, 104(1), 71–87

Seger, J. and Stubblefield, J.W. (2002). Models of sex ratio evolution. In I.C.W. Hardy (ed.), *Sex ratios: Concepts and research methods* (pp. 2–25). New York: Cambridge University Press

Shennan, S. (1997). *Quantifying archaeology* (2nd ed.). Edinburgh: Edinburgh University Press

Sijpesteijn, P. (2007). The Arab conquest of Egypt and the beginning of Muslim rule. In R.S. Bagnall (ed.), *Egypt in the Byzantine world, 300–700* (pp. 437–459). Cambridge: Cambridge University Press

Simpson, S.J. (1995). Death and burial in the Late Islamic Near East: Some insights from archaeology and ethnography. In S. Campbell and A. Green (eds), *The archaeology of death in the ancient Near East* (=*Oxbow Monographs* 51) (pp. 240–251). Oxford: Oxbow Books

Sjøvold, T. (1990). Estimation of stature from long bones utilizing the line of organic correlation. *Human Evolution*, 5, 431–444

Slaus, M. (2000). Biocultural analysis of sex differences in mortality profiles and stress levels in the late medieval population from Nova Raca, Croatia. *AJPA*, 111(2), 193–209

Smith, B.H. (1984). Patterns of molar wear in hunter-gatherers and agriculturalists. *AJPA*, 63(1), 39–56

Smith-Guzmán, N.E. (2015). Cribra orbitalia in the ancient Nile Valley and its connection to malaria. *International Journal of Paleopathology*, 10, 1–12

Sokal, R.R. and Rohlf, F.J. (1995). *Biometry: The principles and practice of statistics in biological research* (3rd ed.). New York: W.H. Freeman

Steckel, R.H., Larsen, C.S., Sciulli, P.W., and Walker, P.L. (2006). *Data collection codebook*. Columbus: The Global History of Health Project

Steckel, R.H. and Rose, J.C. (eds). (2002). *The backbone of history: Health and nutrition in the Western Hemisphere*. Cambridge: Cambridge University Press

Steckel, R.H., Sciulli, P.W., and Rose, J.C. (2002). A health index from skeletal remains. In R.H. Steckel and J.C. Rose (eds), *The backbone of history: Health and nutrition in the Western Hemisphere* (pp. 61–93). Cambridge: Cambridge University Press

Strzałko, J. (1971). Metody rekonstrukcji wzrostu człowieka na podstawie pomiarów szkieletu (Methods of human growth reconstruction based on skeleton measurements). *Przegląd Antropologiczny*, 37(2), 295–314 (in Polish)

Taher, M.A. (1998). Les séismes à Alexandrie et la destruction du phare. In C. Décobert and J.-Y. Empereur (eds), *Alexandrie médiévale 1* (=*Études Alexandrines* 3) (pp. 51–56). Cairo: Institut français d'archéologie orientale

Tkaczow, B. (1988). *Aleksandria: najjaśniejsza, najpiękniejsza, najświetniejsza* (Alexandria: the brightest, the most beautiful, the most splendid). Warsaw: Krajowa Agencja Wydawnicza (in Polish)

Tkaczow, B. (1993). *The topography of ancient Alexandria: An archaeological map*. Warsaw: Zakład Archeologii Śródziemnomorskiej Polskiej Akademii Nauk

Tkaczow, B. (2000). The historical topography of Kom el-Dikka. Notes on plans XII–XV. In Z. Kiss, G. Majcherek, H. Meyza, H. Rysiewski, and B. Tkaczow, *Fouilles polonaises à Kôm el-Dikka (1986–1987)* (=*Alexandrie* 7) (pp. 131–143). Warsaw: Centre d'archéologie méditerranéenne de l'Académie polonaise des sciences

Todd, T.W. (1920). Age changes in the pubic bone I. The male white pubis. *AJPA*, 3(3), 285–334

Todd, T.W. (1921). Age changes in the pubic bone II. The pubis of the male Negro-white hybrid. III. The pubis of the white female. IV. The pubis of the female Negro-white hybrid. *AJPA*, 4(1), 1–70

Toombs, L.E. (1985). *Tell El-Hesi: Modern Military Trenching and Muslim Cemetery in Field I (Strata I-II)*. Wilfrid Laurier University Press

Trotter, M. and Gleser, G.C. (1952). Estimation of stature from long bones of American Whites and Negroes. *AJPA*, 10(4), 463–514

Trotter, M. and Gleser, G.C. (1958). A re-evaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. *AJPA*, 16(1), 79–123

Trotter, M. and Gleser, G.C. (1977). Corrigenda to "Estimation of stature from long limb bones of American Whites and Negroes," American Journal Physical Anthropology (1952). *AJPA*, 47(2), 355–356

Ubelaker, D.H. (1978). *Human skeletal remains: Excavation, analysis, interpretation*. Chicago: Aldine Publishing Company

Udovitch, A.L. (1996). Medieval Alexandria: Some evidence from the Cairo Genizah documents. In *Alexandria and Alexandrianism: Papers delivered at a symposium organized by the J. Paul Getty Museum and the Getty Center for the History of Art and the Humanities and held at the Museum, April 22–25, 1993* (pp. 273–284). Malibu, CA: J. Paul Getty Museum

Udovitch, A.L. (2002). Alexandria in the 11th and 12th centuries. Letters and documents of the Cairo Geniza merchants: An interim balance sheet. In C. Décobert (ed.), *Alexandrie médiévale 2* (=*Études Alexandrines* 8) (pp. 99–112). Cairo: Institut français d'archéologie orientale

Waldron, T. (2009). *Palaeopathology*. Cambridge: Cambridge University Press

Walker, P.L., Bathurst, R.R., Richman, R., Gjerdrum, T., and Andrushko, V.A. (2009). The causes of porotic hyperostosis and cribra orbitalia: A reappraisal of the iron-deficiency-anemia hypothesis. *AJPA*, 139(2), 109–125

Walker, P.L., Johnson, J.R., and Lambert, P.M. (1988). Age and sex biases in the preservation of human skeletal remains. *AJPA*, 76(2), 183–188

Wapler, U., Crubézy, E., and Schultz, M. (2004). Is cribra orbitalia synonymous with anemia? Analysis and interpretation of cranial pathology in Sudan. *AJPA*, 123(4), 333–339

Wasterlain, S.N., Hillson, S., and Cunha, E. (2009). Dental caries in a Portuguese identified skeletal sample from the late 19th and early 20th centuries. *AJPA*, 140(1), 64–79

White, T.D. (2000). *Human osteology* (2nd ed.). San Diego, CA: Academic Press

Wiercińska, A. (1983). Studies on sexual dimorphism in postcranial skeleton, based on the chronoterritorial samples from Kielce district (Poland). *Bulletins et Mémoires de la Société d'Anthropologie de Paris*, 10(1), 119–134

Wikipedia. (2020a). *Normal distribution*. Retrieved from https://en.wikipedia.org/wiki/Normal_distribution (accessed: 07.09.2020)

Wikipedia. (2020b). *Yates's correction for continuity*. Retrieved from https://en.wikipedia.org/wiki/Yates%27s_correction_for_continuity (accessed: 12.09.2020)

Wilcox, R.R. and Keselman, H.J. (2003). Modern robust data analysis methods: Measures of central tendency. *Psychological Methods*, 8(3), 254–274

Wilfong, T.G. (1998). The non-Muslim communities: Christian communities. In C.F. Petry (ed.), *The Cambridge history of Egypt* I. *Islamic Egypt, 640–1517* (pp. 175–197). Cambridge: Cambridge University Press

Wolański, N. (2008). *Ekologia człowieka: podstawy ochrony środowiska i zdrowia człowieka* I. *Wrażliwość na czynniki środowiska i biologiczne zmiany przystosowawcze* (Human ecology: basics of environmental and human health protection I. Sensitivity to environmental factors and biological adaptation changes). Warsaw: Wydawnictwo Naukowe PWN (in Polish)

Wood, H.O. and Neumann, F. (1931). Modified Mercalli intensity scale of 1931. *Bulletin of the Seismological Society of America*, 21(4), 277–283

Wood, J.W., Milner, G.R., Harpending, H.C., and Weiss, K.M. (1992). The osteological paradox: Problems of inferring prehistoric health from skeletal samples. *Current Anthropology*, 33(4), 343–370

Wright, L.E. and Yoder, C.J. (2003). Recent progress in bioarchaeology: Approaches to the osteological paradox. *Journal of Archaeological Research*, 11(1), 43–70

Zar, J.H. (2010). *Biostatistical analysis* (5th ed.). Upper Saddle River, NJ: Prentice Hall

Żurawski, B. and Mahmoud El-Tayeb. (1994). The Christian cemetery of Jebel Ghaddar North. *Nubica*, 3(1), 297–317

INTRODUCTION

Attracting the attention of travelers, scholars and conquerors ever since its establishment in 332 BCE, Alexandria ad Aegyptum has sustained a mythical appeal for generations (Fraser 1993: 93–94; Haas 1997: 8). Literally next to Egypt, but not part of it, it was the best known city of this name, profiting the most from the legend of its titular founder, Alexander the Great (Haas 1997: 7; Saunders 2007). It became one of the most important focal points of European interest in the area after Napoleon's expedition returned Egypt to the Western world. This interest was channeled to the pre-modern history of the city which—judging by the bulk of popular publications—ended with the Arab conquest. In consequence, little research has been devoted to the following Islamic period. This study goes beyond that turning point but it still reaches back to earlier times, especially to the period referred to here interchangeably as "late antique" and "Byzantine", which started in Alexandria with the division of the Roman Empire in 395 CE. Regardless of which adjective is used ("ancient" and "Roman" is also used in this volume for the periods, respectively, from the foundation of the city about 332 BCE, and from its capture in 30 CE), they refer to a time before the Arabs took the city in 642 CE. While there is no general consensus regarding the periodization of the history of Egypt after the Arab conquest (Schick 1998: 80), the author has opted to follow a broad dating of the early Islamic period suggested by published archaeological finds from various Islamic regions (e.g., Francis 1989: 21; Freestone 2006; Kucharczyk 2015: 74). This period (which is referred to as medieval only in relation to the European Middle Ages), ends after the Ayyubids with the transition to the Mamluk period. The Mamluk period terminated in 1517 on the eve of the coming of Ottoman rule to Egypt. When they arrived, the Ottomans found Alexandria in ruin and almost completely abandoned (Kubiak 1998: 19). The city rose again but not before the 19th century.

The discovery and exploration—in the 1960s and 1970s—of medieval houses and a vast burial ground within the district of Kom el-Dikka in downtown Alexandria was an exemplary exception to the general rule of avoiding exploration of early Islamic layers considered as being of secondary importance to the historically earlier depositions (see e.g. Sijpstain 2007: 438) that were the prime focus of most researchers. The obvious benefit of such an approach is a minimization of costs of exploring remains not directly related to the main object of study. An additional factor that has weighed heavily on the exploration of funerary remains from Islamic layers is the question of potential ethical issues (A. Petersen 2013: 253; Macklin 2004: I, 2, 19-25). Coupled with the shortcomings of indigenous archaeology, especially in terms of resources, this has resulted in a generally underdeveloped state of the archaeology of Islam, especially in the eastern Mediterranean where there is an abundance of spectacular finds from earlier periods. The excavations, carried out since the 1960s by a Polish–Egyptian Archaeological and Conservation Mission from the Polish Centre of Mediterranean Archaeology University of Warsaw, fall well within this description, the focus being from the start on the remains of Graeco-Roman Alexandria. However, the historically later depositions were treated with no less conscientiousness and the project, now entering the seventh decade of continuous archaeological exploration, has produced extensive data largely questioning the commonly repeated (with notable exceptions, M. Frenkel 2014: 5–6) stereotype of Alexandria as a gradually depopulated and shrinking metropolis after the Arab conquest in the mid-7th century CE.

The data set from the Kom el-Dikka early Islamic burial ground now consists of nearly 1000 explored graves and more than 2500 individuals examined up to bioarchaeological standards. More numerous series of Islamic-age burials that can be assigned to a Muslim population exist, e.g., 4500 individuals buried in Écija in southwestern Spain (Pomeroy and Zakrzewski 2009: 51), but so far bioarchaeological analyses have been published of only a few dozen of this number (Inskip et al. 2019; Pomeroy and Zakrzewski 2009; Cashmore and Zakrzewski 2007). Conversely, nearly 900 Bedouin burials from the famous site of Tell el-Hesi near Gaza have been subjected to bioarchaeological analyses (Eakins 1993; Toombs 1985). By all standards, the Kom el-Dikka sample is a substantial, indeed the most numerous Islamic skeletal series available from Egypt, and, despite the gaps in the record, a promising study set for bioarchaeological studies.

Earlier presentations of this set of data have largely avoided discussing the historical and archaeological context of the finds. To date, the most comprehensive study using the material from Kom el-Dikka was a volume on the stature of the medieval inhabitants of Alexandria, published in 1985 by Elżbieta Promińska. The reports on the skeletal material that have appeared since then have focused on specific parts of the cemetery, without attempting a holistic approach (e.g., Rysiewski 2000; Mahler 2007; 2012). In view of new data from the examination of hundreds of burials and skeletons accumulated since the 1980s and the expanding potential of osteological research fueled by advances in methodology and the growing understanding of the role played by medieval Alexandria in Islamic Egypt, the author felt it warranted to undertake a comprehensive review of the material.

Popularization of personal computers and the exponential growth of their computational power allowed easy and very cost effective application of a wide array of analytical and statistical tools. Their use in the analysis of this archaeological skeletal series promised to give a more comprehensive picture than that evoked in the published works to date. Modern software which ensure relative ease in the exploration, transformation and visualization of data, supported by statistical tools permitting dynamic change of parameters, equally simple for small and large data sets, have also given greater freedom in exploring tracks that would otherwise have been considered as unpromising. Study limitations, foremost the labor intensity of comparisons prepared by hand, presumably dissuaded earlier researchers from dealing with more than one aspect at a time, be it age-at-death (Promińska 1972) or stature (Promińska 1985).

A firm basis for studying aspects previously excluded from the investigation was created when the published data sets from more than half a century of exploration and anthropological analyses (see Chapter 3.2 for bioarchaeological sources), even if compromised by poor preservation of the skeletal material, were considered in conjunction and supplemented with unpublished data. Access to these observations, coupled with an array of methods from the fields of archaeology and human osteology, prepared the ground for a new comprehensive and multi-faceted analysis of the available data. The study has looked at the changing living conditions of an urban population from the perspective of data to be gleaned from the burials in the Kom el-Dikka cemetery, reflecting indirectly on the social and cultural realities of Alexandria in one of the least well known periods of its history; at an early phase of Islamic domination.

Study structure

The study is structured in a complementary way, the primary osteological part of the research drawing on a detailed examination of the archaeological evidence. To ensure clarity of presentation, the bioarchaeology has been separated from the history and archaeology. This approach was dictated by the different and uneven data sets emerging from the long period of research.

The first part contains a description of the cemetery, preceded by a discussion of the socio-historical setting of the site and the transformation of the city under Arab rule. The emergence of the burial ground, its changing extent over the ages and its phasing are discussed, marshalling evidence from historical and archaeological sources. This has been coupled with a reexamination of standing cemetery chronology, essentially putting into perspective the results, minor and major, of the osteological studies presented in the second part.

The bioarchaeological section brings together data on the skeletal material and dentition, including historical osteological research as well as the author's own investigations completed over the past dozen years or so. The historical population emerging from the analysis is examined for evidence of changing living conditions in Islamic Alexandria over the ages. This part is independent of the first, applying different research methodologies to a different set of sources, and arriving at conclusions of a different kind. In confrontation with the results of the historical and archaeological parts, the discussion of the bioarchaeological analyses generates a credible picture of the changing conditions of life in Alexandria during a period of a growing dominance of Islam in Egypt between the 9th and the 12th century.

Data acquisition and processing

The most demanding element of this study was the unification of a set of excavation data coming from more than half a century of excavations, even if the section of the work constituted by the Islamic cemetery on Kom el-Dikka could be considered as relatively narrow. The challenge was magnified by the need to use research tools not applied before to understand, or at least to ensure that there is a chance to understand, the spatial relationship of burial features in the cemetery.

Visualization was the first step, even if only in the form of an ordinary plan, like *Fig. 8* below, but supplemented with information that could not be presented in the printed plan of the whole site. The visualization prepared using QGIS software was limited to two dimensions and models of tombs were made as simple as possible. The idea was to produce an interactive plan of the cemetery, in which selecting a tomb structure would bring up the related data set from the catalog. It facilitated both the data acquisition and subsequent analysis, but for the purpose of the current publication only non-interactive views of a plan and the plain data were deemed essential.

The database structure prepared for the present study included more fields than the cleaned and verified one presented in the catalog (see below, Appendix and online catalog). The first version included separate tables for data from plans, catalogs, journals, anthropological analyses and published lists. Information tended to be repeated and was sometimes contradictory. The data were unified as far as possible and combined in the same way as card catalogs, creating a set of relationships linked by index numbers. An effort was made to separate the presentation layer (GIS site plan) from data other than that required for the visualization, because of the inherent problem of gaps in the documentation. In effect, the number and inventory markings of the graves on the plan do not necessarily match those from documents of a different type.

The process of data acquisition was shaped by the nature of available sources, chiefly plans and sketches. Numbers and locations were read from the paper plans, as was also the data to describe the structure of each digitized burial feature. The underground and aboveground parts of the tomb were treated separately from the start, while retaining the possible relations between them. A grave, or rather a grave unit, was considered as consisting of no less than one underground feature and in the case of no information on an underground feature, then at least a single superstructure. Ideally, a single grave consisted of a grave box underground and a superstructure aboveground. Whenever subterranean structures were composed of more than one feature, it was necessary to decide whether the features identified in the documents belonged to separate graves or represented different features of the same grave. A further difficulty that did not compromise the process as such were the different numbers sometimes assigned to the underground and aboveground structures, even if the two were undoubtedly connected.

Much attention was accorded to the process of scaling and positioning of the features in relation to the architecture around them. Altogether 81 different plans with tomb structures from the different sectors of the cemetery were superimposed on an excavation plan of the late antique architecture (including architectural remains from earlier phases of occupation in the so-called Theatre Portico and in sector U). Wherever sources were lacking, especially in the case of sectors W1 and L2, considerably less detailed collective plans were used to fill in the gaps in the grave records (Tkaczow 2000: Pls XIV–XV). The gaps that became apparent after the inclusion of all of the extant sketches [*Figs 24–27*] were interpreted in keeping with the available documentation and existing publications, consulting specific instances with the long-time head of the excavations, Grzegorz Majcherek from the Polish Centre of Mediterranean Archaeology University of Warsaw. The plan also includes the so called Tulunid defense wall, running in the immediate neighborhood of the excavation site, as well as the antique street network around it. The reason behind this is that tombs of a form and foundation level that made them a likely continuation of the Islamic necropolis from Kom el-Dikka had been discovered there in trenches dug on the occasion of a number of archaeological salvage projects (Tkaczow 2000: Pls XIV–XV).

In the rare instance of a published version being available beside the original documentation, the two sources were compared in order to eliminate potential errors. The published versions were deemed more trustworthy, the assumption being that excavators were apt to critically review plans for publication. The informative value of these images, which are of key importance for the overall site plan, varied. Nonetheless, the choice of a simplified model of illustrating tomb features, reduced to polygons encircling the remains of every grave feature, which is the simplest form in this case, enabled even the poorest of these images to be included on equal terms in the output set.

The next step was to add data from other collections. For each element, it was like a new layer being superimposed on the existing resource, verifying existing records and creating new ones, albeit devoid of graphic representation in the GIS part of the base. When merging the osteological and archaeological data, the archaeological data was supplemented with information from grave descriptions accompanying the analyses published by anthropologists (Dzierżykray-Rogalski 1962; Promińska 1985; 1972).

The catalog available online (doi: 10.18150/SAWU9S; see below, Appendix) presents the data used in this book and should be considered as the most up-to-date version of the available documentation. A project to publish the GIS database of the cemetery is currently underway.

Chapter 1

ALEXANDRIA UNDER ARAB RULE: THE SOCIO-HISTORICAL SETTING

Describing early Islamic Alexandria in a historical perspective is a task in itself and resorting to written documents requires the same kind of professionalism and specialist attention that is afforded other categories of sources. The acquired information is far from straightforward and the quality of this study would weigh heavily upon the results of any such analysis, hence the decision not to exceed the frame afforded by mostly published evaluations of historical sources and the publications and manuscripts of modern scholars, which are *de facto* the written sources for this research, even if not in the historical sense. Arabic works, particularly of historians and chroniclers of the conquest (Ibn ʿAbd al-Ḥakam, *Futūḥ miṣr wa'l maghrab wa'l andalus*; ʾAḥmad ibn Yaḥyā al-Balādhurī, *Kitab Futuh al-Buldan*, and numerous works of Taqī al-Dīn Aḥmad al-Maqrīzī),[1] works of Egyptian Christians (especially the *Chronicle* by John of Nikiou and *History of the Patriarchs*),[2] the Cairo Genizah Collection, an important source for medieval Egypt including Alexandria, and European reports of diplomatic and trade contacts in Mamluk times (see Gourinard 2012) are referred to after the specialists.

The doctoral dissertation of Władysław B. Kubiak, *Archeologia muzułmańskiej Aleksandrii do okresu wypraw krzyżowych* [The archaeology of Islamic Alexandria until the Age of the Crusades] (1965), served the author as a good introduction to the history of the city within the timeframe of the current study, supplemented by the same author's article "Nowe badania w Aleksandrii w zakresie archeologii islamu: szkic" [New research in Alexandria in the field of Islamic archaeology: a sketch] (Kubiak 1998). Important sources for understanding the situation of the city at the time of the conquest and directly after it include Clive Foss's "Egypt under Muʿāwiya Part II: Middle Egypt, Fusṭāṭ and Alexandria" (2009) and the last chapter in Christopher Haas's book *Alexandria in Late Antiquity: topography and social conflict* (1997). The conquest itself is well described in the classic study by Alfred J. Butler, *The Arab conquest of Egypt and the last thirty years of the Roman dominion* (1902) and a popular book by Hugh Kennedy, *The great Arab conquests: how the spread of Islam changed the world we live in* (2011).

The historical complexities of the period from an Egyptian perspective are explained in *The Cambridge History of Egypt*, volume one on *Islamic Egypt, 640–1517* edited by Carl F. Petry (1998). Detailed information, especially on medieval Alexandria, comes from a special edition of the *Al-Masaq* journal entitled *Cosmopolitanism in Medieval Alexandria*, and from articles by Abraham Udovitch, "Medieval Alexandria: some evidence from the Cairo Genizah documents" (2002) and "Alexandria in the 11th and 12th centuries: letters and documents of the Cairo Geniza merchants: an interim balance sheet" (1996). Alexandrian early Islamic history in the context of Egypt as a whole is presented by Petra M. Sijpesteijn in her "The Arab conquest of Egypt and the

[1] For references to English translations of these sources see, e.g., Mikhail 2014: 385–391.
[2] See, e.g., Mikhail 2014: 385–391.

beginning of Muslim rule" (2007), a chapter in the volume *Egypt in the Byzantine world, 300–700*. Her work introduced the concept of cultural transformation to the present study.

1.1 Alexandria under Arab rule

The coming of Arab rule to this cosmopolitan Mediterranean city with its splendid ancient past obviously changed the face of the city, even if not at once. It was April 641 when general Amr ibn al-A'as led his forces against Alexandria. Over a year later, in September 642, the gates were opened to the victorious army and the Byzantine troops were allowed to leave the city. The Arabs moved the power center of Egypt from Alexandria to Fustat, an army camp set up by Amr ibn al-A'as following the capture of Babylon after a long siege the year before (Foss 2009: 268; Kennedy 2011: 137–140). The location of Fustat, situated at the apex of the Nile Delta, between the desert regions of Upper Egypt and the fertile plains of Lower Egypt, was better suited to extend control over all of Egypt (Kubiak 1987: 60) and strategically less threatened by the Byzantine raids that plagued the coast for the next few hundred years (Foss 2009: 268). The move, which came in 674 when the main naval yard was moved to Fustat, ultimately determined Alexandria's fate. It undermined the city's position, marking a shift of both economic and cultural life in Egypt away from the Classical Mediterranean (Foss 2009: 269).

Briefly in 645, the Byzantine general Manuel with a fleet of 300 ships reconquered the city (Kaegi 1998: 55, 59–61; Lane-Poole 1901: 20–21). When Amr ibn al-A'as returned, he treated the insubordinate city with much less benevolence (Haas 1997: 339). Nonetheless, Alexandria retained its position as a prosperous commercial center and the second city in Egypt (M. Frenkel 2014: 6) for another hundred years at the very least, thanks to a strategic position on the coast and frequent brigand raids launched along the Mediterranean shore (Kubiak 1998: 18). The Arabs' declining interest in trade goods from the north, chiefly oil and wine, gradually relegated the Mediterranean metropolis to a peripheral role. Supplanting imported ceramics with pottery of local production (Foss 2009: 271–272) is a manifestation of Egypt's increasing independence from the sea trade, which was Alexandria's mainstay. It became more like a distant suburb of Fustat, little more than a "geographical point of entry" with an autonomic market, but with limited possibilities (M. Frenkel 2014: 6). It remained *ad Aegyptum* in character, although weakened, at least until the second half of the 10th century (Kubiak 1998: 18). By the end of the 11th century, it had lost its special status and had become deeply integrated with the Egyptian state of the time (Bramoullé 2008: 107; M. Frenkel 2014: 7; Udovitch 1996: 282–283; 2002: 100), although it retained some of its independence also under the Fatimids, taking advantage of its exceptional position (Sanders 1998: 167), second only to Fustat.

Writing of the role of the southern districts of Alexandria in the economy of the city as well as Egypt as a whole, Peter M. Fraser (1993: 101) pointed indirectly to the cause of the later decline of the city. These districts connected Alexandria to the Mareotis Lake and the network of navigable canals that were part of the transport system which played a key role in the grain trade. It goes without saying that this part of the city was deserted after the Arab conquest. When the Abbasids fortified Alexandria again in the mid 9th century (Kubiak 1998: 18–19; Rodziewicz 1998: 370), the southern part of the Roman city, which opened onto the canals and the Mareotis Lake, found

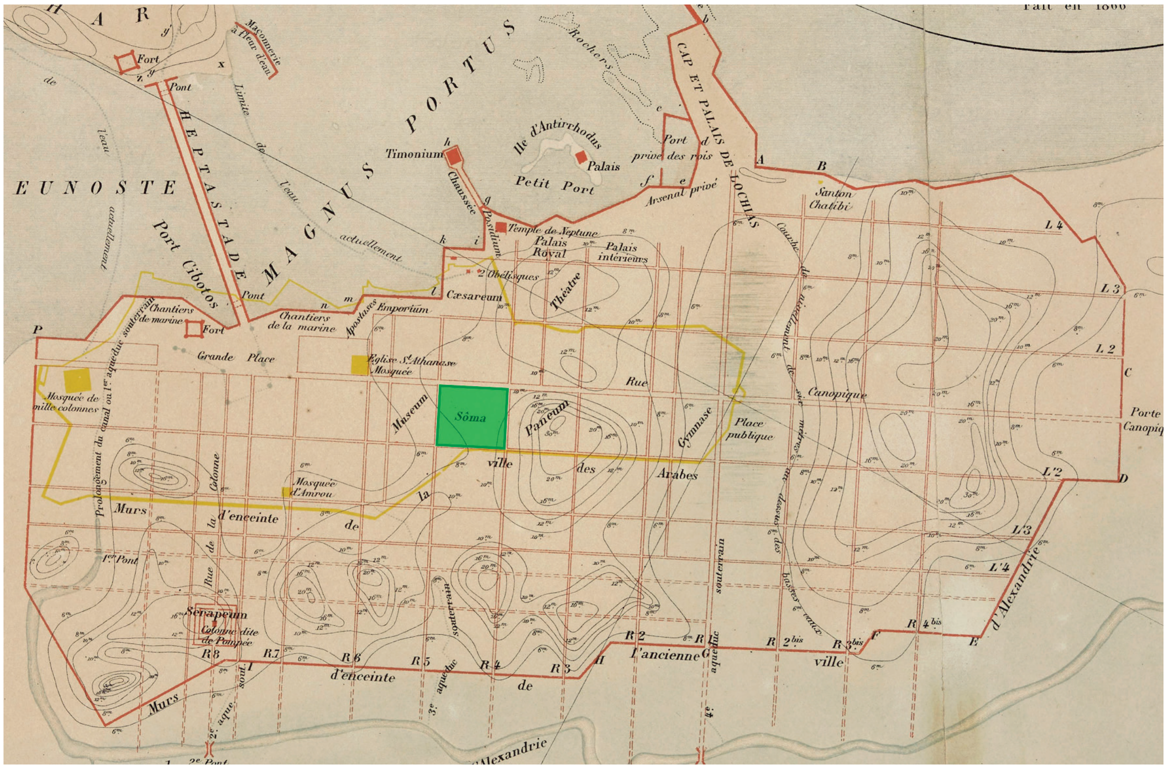

Fig. 1. Alexandria in antiquity and medieval times as mapped by Mahmoud Bey, the walls of ancient Alexandria are marked in red, those of the medieval city in yellow; the green rectangle superimposed on the plan indicates the location of the archaeological site on Kom el-Dikka

itself outside the new walls[3] [*Fig. 1*] and at risk from raiding parties. The Crusaders, when they came in 1174, destroyed the beautiful gardens in this area (M. Frenkel 2014: 10), although in truth of the matter, the walls did not protect the city itself from plunder. The second blow to the economy of the city was delivered by the Nile. When the Canopic branch of the river declined and finally disappeared (Fraser 1993: 101), it caused a significant increase in the expenditures required to maintain the navigability of existing canals. The water transport system also did not fare well considering the Arab administration's relative disinterest in maintaining hydrological installations in good condition.[4] Sources from the end of the 12th century lament on the condition of the canals bringing water to the city and constituting at the same time the main transport route for goods to and from inland Egypt (M. Frenkel 2014: 13–15). Consequently, by the 13th century Rashid had replaced Alexandria as Egypt's primary Mediterranean harbor (Rodziewicz 2002: 5–6, 9).

[3] These defenses will continue to be referred to as Tulunid in this study, as is common practice in the literature (Tkaczow 2000: Pls XIV–XV), despite the fact that their construction, as described above in the introduction, actually preceded the reign of the Tulunids in Egypt (Kubiak 1998: 18–19; Rodziewicz 1998: 370) and Ahmad Ibn Tulun's role was limited to a reconstruction of standing fortifications (Bianquis 1998: 98–99; Isma'il 1993: 155).

[4] Kubiak (1998: 16, 18) describes the Arab administration's general reluctance to finance the maintenance of urban water installations; it may be assumed that a similar reluctance would have also concerned the transport canals outside the city.

The following centuries were a history of gradual depopulation and atrophy of the urban tissue until it became—there is no way to determine when exactly—a small border town. At the end of Mamluk rule in Egypt, the once "most illustrious, most beautiful, and most magnificent" Alexandria, as runs the title of a popular book about it (Tkaczow 1988; revised English edition 2019), the inhabited area was reduced to just the central part of the Heptastadion, the causeway that connected the mainland to the island of Faros. Yehoshua Frenkel (2014: 88) argues convincingly that the provincial status of Alexandria, so perceived by the most prominent people in the Sultanate, who saw in it a distant and unimportant border harbor with a prison, was at the root of this process. This particular attitude to Alexandria is confirmed in the written sources for the 15th century, but it very likely concerned the "waning city" (Y. Frenkel 2014: 91) also earlier. Its source lay most probably in the Mamluk's "defensive maritime policy", which called for fortifying the coast against raiders; from this perspective, the coastal localities were little more than a security buffer zone for the Mamluk state (Y. Frenkel 2014: 81). For the Europeans it had perhaps retained its function of a transit port between inland Egypt and the outer world, but in reality Rashid and Damietta had long since taken over its economic role (Y. Frenkel 2014: 91).

The coming of the Ottomans in 1517 found Alexandria neglected and deserted, and little changed until the 19th century when the governor of Egypt Muhammad Ali made it once again Egypt's second city, a vibrant cosmopolitan Mediterranean center that it has remained until this day.

1.2 Population change

The perspective of a burial ground necessitates a closer look at the population inhabiting the city, forming a general idea of how populous it was and the fluctuations it underwent in the period in question. It can be assumed that the patterns of change starting after the conquest paralleled the historical transformation. After the conquest the Arabs quartered a garrison of 12,000 soldiers to secure the coastal metropolis (Haas 2006: 345), stationing them in uninhabited houses within the circuit of the city walls. More troops 15,000 strong arrived shortly (Foss 2009: 272). How populous was a city that required close to 30,000 men to police it?

In the middle of the 7th century Byzantine Alexandria was no longer the proud metropolis of Roman times with a population estimated at about 500,000–600,000 (Bagnall and Frier 1994: 54; Delia 1988: 284). In the years immediately preceding the Arab conquest, it had already shrunk considerably due to incessant social unrest, natural cataclysms and a rising sea level (Fraser 1993: 98–101). The first plague pandemic started in Pelusium in 541 and quickly spread all over the Mediterranean (Little 2006: 3, 8–9), recurrent bouts decimating the Egyptian population for the next two centuries. According to Josiah C. Russell (1966: 17), the plague was responsible for a 25% drop in population numbers during the first 50–60 years. The inevitable depopulation of Alexandria because of these factors must have greatly diminished the city that fell to the Arabs in the mid 7th century. The Persians added significantly to the general decline, conquering the city in 619 and occupying it for more than ten years.

The exodus of the Byzantines after the coming of the Arabs in 642 diminished the urban population even further. Those with ties to the previous authorities, the garrison, the Christian Orthodox Church and the social elite in general would have left as well (Kubiak 1998: 18).

The attempt to retake the city in 645 and the defeat of the expedition in the next year must have aggravated the situation even more (Sijpesteijn 2007: 441). According to Kubiak (1998: 18), of the former elites only the Monophysite hierarchy and administration remained, filling the void left by departing Byzantine officials and the privileged Melkites (Butler 1902: 450), although more recent research has shown the position of the Monophysites in the second half of the 7th century to be not as prominent as previously assumed (Mikhail 2014: 39–40). Considering the impossible numbers that are quoted, the Arab sources most probably exaggerated the victory of 642. A later source reported 30,000 men, this out of the total of 200,000 living in the city, fleeing the city to escape the conquering army (Delia 1988: 285–286). These numbers could be considered as probable only if describing the entire population, including women and children.

Haas's estimate of Alexandria's population at the time of the Arab conquest, which stands at 200,000 (Haas 1997: 340), appears reasonable in the face of all the ensuing catastrophes that brought down the splendid city of Roman times. The considerable depopulation of the city over the ages was reflected primarily in the undisputed abandonment of certain districts, but also in a change of burial practices, allowing Christian graves to be located within the city walls. All factors considered, it seems reasonable to follow Delia (1988: 284) in her estimates of the total population of Alexandria in Roman times and to conclude that it would be surprising if at the time of the Arab conquest it exceeded a range of 200,000 to 300,000 people.

Further deterioration of the population situation under Arab rule was inevitable, following the transfer of the capital to Fustat and the rapid isolation of Egypt from the Mediterranean world. But the actual slump came after more than a century (Kubiak 1998: 18). The severity of the situation was highlighted 200 years after the conquest when, just before the Tulunids' accession to power, two lines of fortifications were constructed, encompassing only a fourth of the territory of the ancient metropolis. This pointedly demonstrated the reduced population of Alexandria at the time. The cemeteries that found themselves inside the new walls also attested to the low density of the population. Taking everything into account, the population of Alexandria in the given period could be estimated at about 60,000–70,000 (Kubiak 1998: 18–19).

It should be noted, although this phase in Alexandria's history is already beyond the scope of this study, that the urban population in Mamluk times was dramatically reduced to just 5000–7000 people said to inhabit only the central part of the Heptastadium (Kubiak 1998: 19).

1.3 Arabization and Islamization

The Arab population that flowed into Egypt after the conquest probably did not exceed 100,000 in all, this estimate being based on data speaking of no more than 40,000 men (Kennedy 2011: 146). Most of the Muslims stayed in Fustat, receiving pay but without permission to settle in the provinces (Butler 1902: 461). One can surely imagine the contempt with which Egyptians who converted to Islam in the early years would have been treated, hence it is rather likely that, if they only had a choice in the matter, they would have moved to Fustat (Sijpesteijn 2007: 453). The religious isolation would not have fanned the rate of new conversions. Indeed, 90 years after the conquest, in the face of the very slow rate of Islamization, the governor of Egypt felt forced to bring 5,000 Arabs into the Delta (Butler 1902: 463–464). The rate of conversion increased only after the newcomers "grew" into Egypt, started cultivating land, established families and entered into close relations with the Copts. Their names began to appear in sources connected with agriculture as late as the middle of the 8th century (Sijpesteijn 2007: 452–453).

Easy conquest of Egypt by the Arabs was not tantamount to immediate Arabization and even more so, an unproblematic Islamization of the population. This unconditional military success, sealed by the defeat of Manuel's expedition, was generally accepted in Egypt where little love was lost for the Byzantines (Kaegi 1998: 60).[5] The continuity of economic, social and cultural models in the everyday life of the people of Egypt was striking (Sijpesteijn 2007: 444). Arabic as a language of communication for the new authorities would have been appealing to all those who saw in the situation a new opening for themselves. Progressing Arabization, like Islamization, was not a violent process. For half a century after the conquest Greek remained the language of the tax administration (Kennedy 2011: 144). Even issues of fundamental importance for the functioning of the Arab community were processed in this language until 706, when the governor of Egypt ordered the *diwan* registers to be prepared in Arabic. In Alexandria, where Byzantine officials were replaced first by Melkites and then by Copts (Mikhail 2014: 27, 39–40), Arabization must have proceeded even more slowly than elsewhere.

For the first fifty years after the conquest the core of the new civil administration was composed of Egyptians who had not become Islamicized (Sijpesteijn 2007: 448); after that they continued to hold important positions in the authorities (Kennedy 1998: 72). Documents from the time of the conquest do not mention the religion of the invaders (Sijpesteijn 2007: 451); it did not become an important issue until later.

In economic terms, the new tax burden, compared to that of Roman times in particular (Butler 1902: 451–454), did not seem onerous. With time, the dropping numbers of Christians and Jews, who were the only ones to pay a poll tax, increased the oppressive nature of these new duties (Wilfong 1998: 182), which stretched also into other than economic aspects of daily life (Butler 1902: 448–449, 643), leading to the Coptic revolts starting from 725–726 (Kennedy 1998: 65, 67). As regards the situation of the inhabitants of Alexandria immediately after the conquest, it was not as evident as that of the people in the provinces. Individuals exempt from taxes for whatever reason under the Romans (Butler 1902: 453–454) must have been hit hard by the new poll tax. In addition, the departure from the city of citizens of substance after the conquest and deteriorating trade must have negatively impacted the economic situation of the inhabitants. In turn, the collapse of Alexandria's lucrative trade was compensated to some extent by frequent raids on Byzantine coastal towns in the early years after the Arab conquest (Foss 2009: 273).

[5] Maged S.A. Mikhail (2014: 25–32) argues convincingly against such a one-sided view concerning sympathies of the Egyptian population both during and after the conquest.

Chapter 2

THE CEMETERY ON KOM EL-DIKKA: ARCHAEOLOGY

No historical community can be studied from a bioarchaeological perspective until the fundamental issue of a chronology of the finds is addressed. The conclusions obviously depend on this, but so does study methodology. Lacking comparative bioarchaeological data from other excavations, one may turn to material from populations distant in time and space, or else use any reasonable key to classify the material from one site in order to create groups that can be compared among themselves. This is true of the Kom el-Dikka cemetery, in the case of which there is a dearth of relevant bioarchaeological studies for comparison from investigated Islamic cemeteries in the region.[1] One could look to regional cemeteries from immediately preceding periods, culturally different in their attribution but still close in time and space. However, comparable data is not readily available, because publishing raw measurements as supplementary material accompanying analytical papers is a relatively new concept in bioarchaeology, and is still frequently avoided. Moreover, comparisons of biological conditions between populations of unknown genetic affinity, and different epigenetic history, hence with potentially different reactions to similar environmental factors, would only introduce new uncertainties. It was, therefore, a natural choice to identify the internal differences in the Kom el-Dikka cemetery that could be instrumental for structuring the analysis.

Early efforts at interpretation (Dąbrowski 1966) had demonstrated the chronology of the remains to be the most obvious form of division of the data set, making the cemetery on Kom el-Dikka a point of reference for itself. All things considered, it was still deemed the most proper approach for a diachronic study of the human skeletal remains. Biological conclusions on social and historical grounds were feasible once a clear determination had been made of the chronological framework as well as the cultural identity of the burials, and for this one needed a precise description of the internal differences according to which the data set was divided.

The Islamic cemetery on Kom el-Dikka spreads over the entire area of an archeological site encompassing key public buildings from the city center of ancient Alexandria. These have been identified as a late antique academic complex composed of more than twenty lecture halls, most of them lining the eastern side of a monumental porticoed square, with the largest of these—the so-called Theatre Building—serving in its latest phase as the biggest lecture hall (Majcherek 2007b: 15–16, 40). The academy was connected with a stately public bath complex supplied with a standard set of amenities including public toilets, supplied with water from a nearby built cistern and dumping extensive amounts of ash from the heating furnaces in the center of the site (Majcherek 2007b: 16). The first graves were dug into the ruins of ancient buildings. The subsequent

[1] The unpublished doctoral dissertation on the cemetery at Quseir al-Qadim on the Red Sea coast of Egypt is a notable exception in this regard (Macklin 2004). However, this material is all but useless from the point of view of the present considerations because of the differences that are presumed to exist between the residents of a 9th–12th century Mediterranean port—Alexandia—and a population from the 14th and 15th century buried in a harbor on the Red Sea coast, which was a major pilgrimage stop on the way to Mecca. In addition, the series in question, consisting of 85 individuals, is relatively small.

accumulation of graves can be divided into two general chronological phases of burial activity on site, designated by researchers as a Lower and an Upper Necropolis (Dąbrowski 1966). The early division also distinguished a Middle Necropolis (Kubiak 1967a), but it is argued below that these particular burials and structures were actually an integral part of the Lower Necropolis. Over the centuries, several meters of rubbish of all kind accumulated over the whole site, including the cemetery, raising by several meters the general ground level in the area [*Fig. 2*].

2.1 Archaeological exploration and sources

The current work encompasses data collected from the site over the course of more than half a century of excavations by the Polish archaeological project. Therefore the history of archaeological activities in the area and the sources that were produced in the process are discussed here collectively.

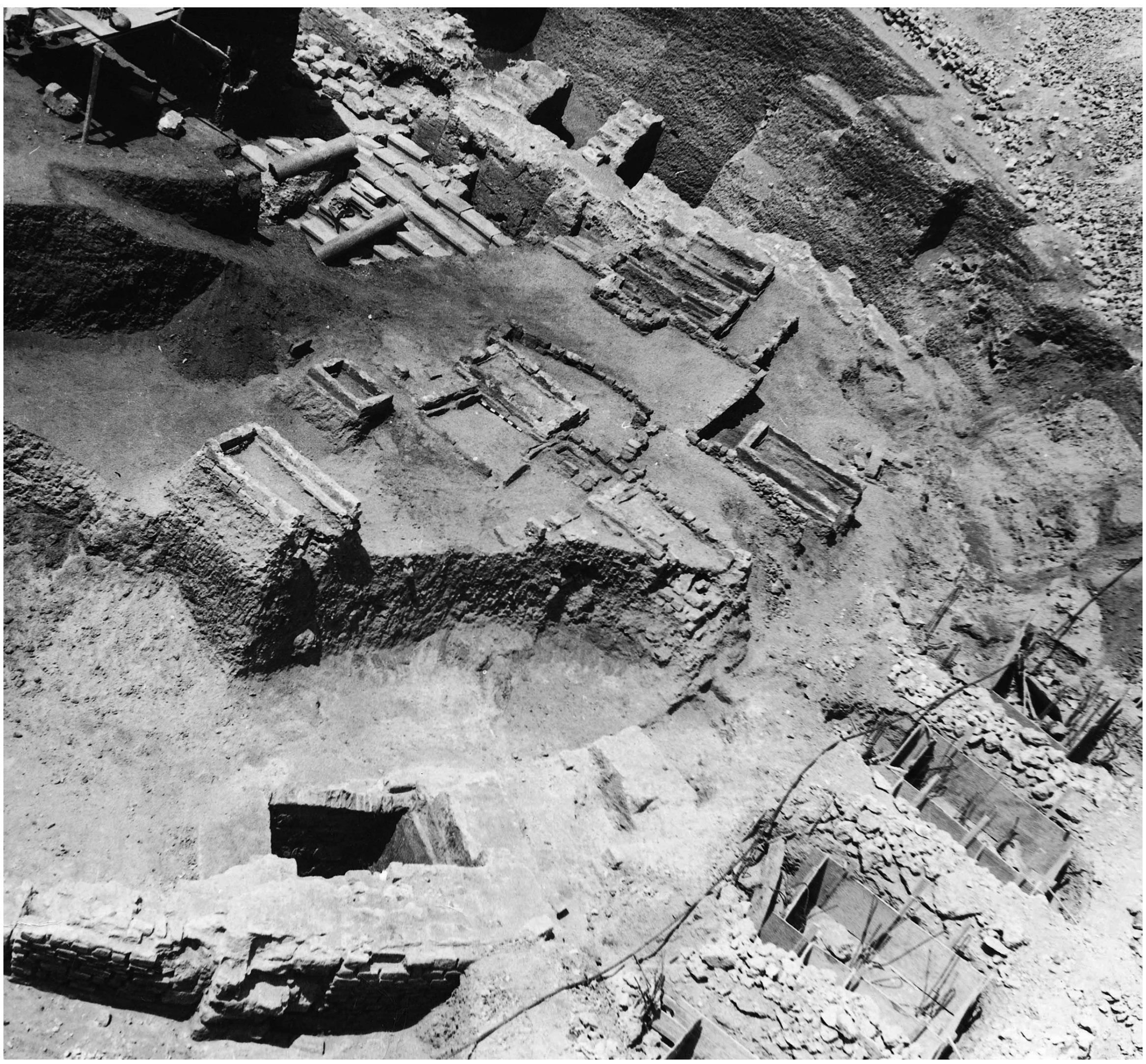

Fig. 2. Graves of the Arab cemeteries in layers above the crown of the theater; excavations in 1964

Generally speaking, the history of archaeological research in Alexandria reaches back to the 1860s when, acting upon an order from the Khedive of Egypt, the astronomer Mahmoud Bey drew up the first plan of the ancient city (Mahmoud Bey 1872) [see *Fig. 1*].[2] Since then, the Polish–Egyptian project at the Kom el-Dikka site in the center of ancient Alexandria is the only one with enough breadth to provide grounds for more general conclusions on the medieval as well as earlier history of the city. The scale of the work, as well as the limitations encountered in the investigation of the cemetery, can be appreciated once the efforts of several different researchers, spread over dozens of years, are outlined in brief.

The largely artificial mound on the site of Kom el-Dikka was the location of a fort built in the Napoleonic era (Dąbrowski 1966: 176) [*Fig. 3*]. The hill was penetrated archaeologically by David George Hogarth already in the late 19th century (1894: 18–22), at a time when the fort still towered over the cityscape. With the help of army engineers he tunneled into the hill from

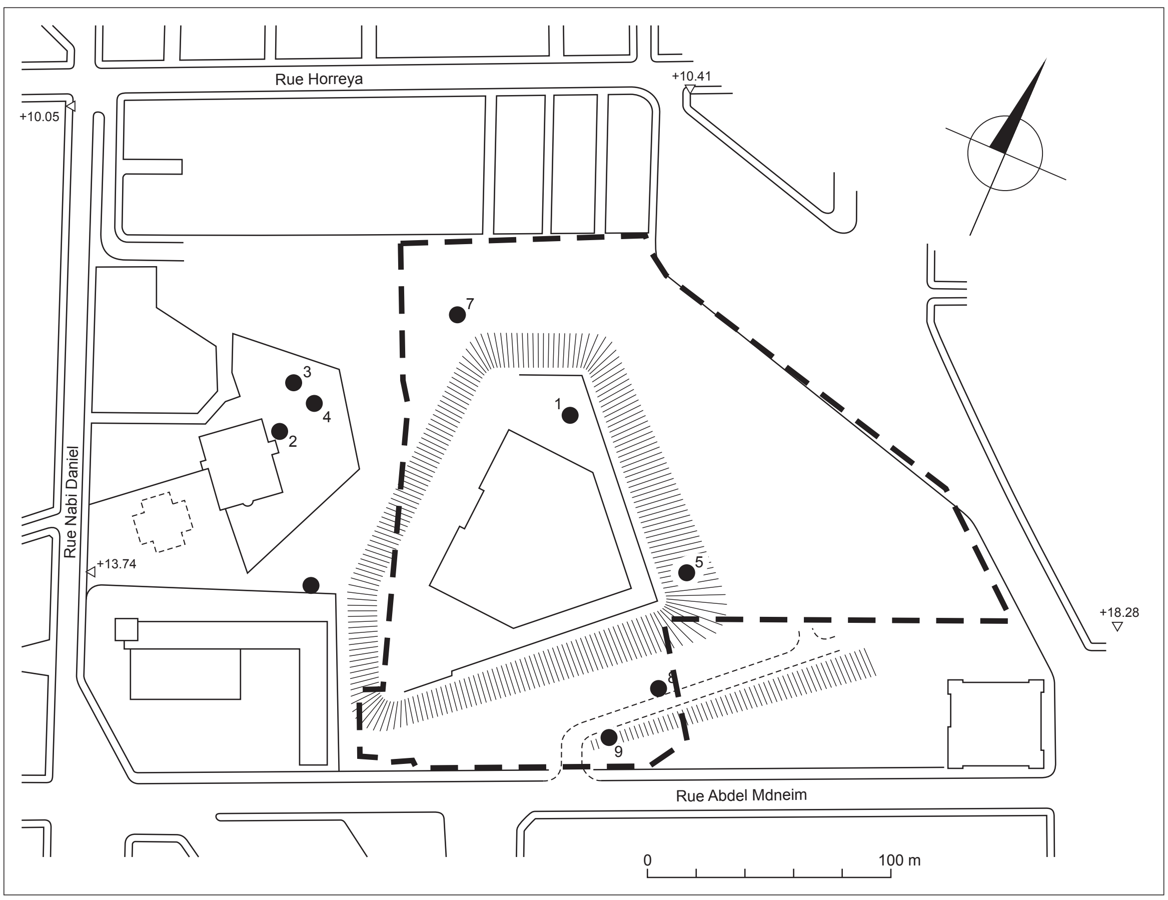

Fig. 3. Plan of the Alexandria city quarter with the archaeological site of Kom el-Dikka and the Napoleonic-era fort still dominating the site (Dąbrowski 1960: Pl. II). Dots mark areas explored before 1958: 1 – excavations of D.G. Hogarth, 2–4 – excavations of E. Breccia, 5–9 – excavations of A. Wace. The boundaries of the site as they are today are shown with a dashed line superimposed on Dąbrowski's original plan

[2] For the most complete list of archaeological sites and finds of historical significance from the territory of Alexandria see Tkaczow 1993.

the side, but abandoned the project after piercing his way through some exceptionally thick brick walls, which he concluded to be part of a Roman residential building; these later turned out to be a huge late Roman public bath (Borkowska-Kołątaj and Kołątaj 1972: 170, 172). Much better results were reached later by Evaristo Breccia (1932: 48–52), Achille Adriani (1940: 55–64) and Victor Guirguis (Promińska 1972: 16). Concentrating on the antique ruins, they documented Islamic remains out of a professional conscientiousness. The first and only project on Kom el-Dikka to focus explicitly on medieval Alexandria—never published—were the excavations by Alan J.B. Wace in 1947 and 1948 (Lane 1949).

The dismantling of the Napoleonic-era fort by the municipal authorities in the 1950s opened the way to a much wider exploration of the hill. The task was undertaken by Kazimierz Michałowski. Following a promising survey in 1958, a Polish team started regular excavations at the Kom el-Dikka site. In the course of 60 years of investigations, a large fragment of the late antique town was cleared and studied. Wherever possible, underlying layers of earlier date, early Roman and occasionally also Ptolemaic, have also been explored. On the whole, however, it is the Byzantine phase of the site that has been investigated more or less completely, its importance for the history of the city and impressive state of preservation making it the nexus of a long-term successful restoration project. It is this quarter that can now be seen when visiting the archaeological park: a complex of public buildings including the lecture halls of a late antique academy and an imperial public bath with a masonry-built cistern (Majcherek 2010; Majcherek 2007b). A residential quarter stretches east of this public complex [*Fig. 4*].

Concealed in the thick accumulation of later depositions, sometimes exceeding 10 m in depth, were the remains of an extensive Islamic burial ground. The graves were successively investigated and recorded, most recently, that is, in the later part of the first decade of the 21st century, by Emanuela Kulicka, working under the supervision of Grzegorz Majcherek, head of the University of Warsaw PCMA expedition to Alexandria.

2.1.1 Archaeological documentation (unpublished)

The exact number of graves excavated in the course of the project could not be established for the purpose of this study despite efforts made by the author to this end. A total of 1975 graves was located on the site plan and the database integrated with it now contains 779 superstructures and 1298 grave pits or boxes. In the case of 71 superstructures and as many as 216 underground features, it proved impossible to track down the original excavation number.

One reason for this is the incomplete nature of the accessible archaeological documentation, even if only the excavations of the Polish–Egyptian team are considered. The first trenches of the Polish project were dug 60 years ago and documentation standards have varied greatly over the course of six decades due to changing team directors and, obviously, staff rotation, not to mention the lesser importance assigned to medieval burial remains from the point of view of the project's objectives. Excavation of the necropolis was after all a prerequisite for the investigation of Graeco-Roman layers and this perspective effectively eliminated 'excessive' documentation due to obvious budgetary restrictions. In consequence, many burials were poorly recorded, through either neglect or ignorance, leaving gaps in the documentation with regard to observations deemed significant for the purpose of the present research. Some of the

Fig. 4. Plan of the archaeological site of Kom el-Dikka in Egyptian Alexandria showing elements of the modern administrative and tourist infrastructure

archaeological documentation that was made was unfortunately lost or destroyed; this concerns in particular plans of sectors W1, W2 and L, as well as the documentation of the Lower Necropolis in Sector U from before 1985.

The archaeological documentation source base for the present study consists of plans, field excavation notes, grave recording sheets and the results of epigraphic analyses of stelae found in the cemetery. All other archaeological sources were considered indirectly, through conclusions and selections made by other specialists (especially pottery contexts, photographic records and individual finds recording sheets).

Excavation plans of the burial ground were available as original documentation (sketches, tracings, and collective plans). Copies of plans that were not available in a digital version (bitmaps and, after 2000, in vectors in CorelDRAW format) had to be digitized. Archival hard copies of plans produced before 1984 are held by the Institute of Mediterranean and Oriental Cultures Polish Academy of Sciences; these were used indirectly through the publications, with a notable exception of a plan of the Upper Necropolis in Sector M. Post-1984 documentation is archived by the Polish Centre of Mediterranean Archaeology, University of Warsaw (PCMA

UW) and the archival resources of the Polish–Egyptian Archaeological and Conservation Mission to Kom el-Dikka in Alexandria, which is a PCMA UW project (for details see the appendix to this chapter).

Plans published in reports as well as synthetic studies (see below, *§ 2.1.2*) were treated as separate sources in view of the fact that they are most likely to have been revised and collated by the excavators in charge. The most important plans used in this study in their published form are presented in the appendix to this chapter.

Grave recording sheets and grave field excavation notes supplied the essential excavation data, ensuring numbering consistency in the course of work and a ready overview of the discoveries in the cemetery across sectors, which is especially important when excavators change or a substantial amount of time passes between the excavation of a superstructure and the matching grave box. The Kom el-Dikka Grave Register is a field inventory taking on the form of running entries in a notebook with each entry describing a single grave feature. In the past excavators were given considerable leeway regarding their notes, which preceded filling out grave recording sheets. The drawback of the system were inconsistent sets of recorded observations from feature to feature, even when documented by the same excavator. For the purpose of the present study, the Grave Register was used almost exclusively to verify inventory numbers of particular grave features. Occasionally, data on the covering of a grave box could be gleaned from these notes.

The formal grave recording sheet, which complements the Grave Register, corresponds to the finds recording sheet with the grave being treated like an artifact. 2004 marked a turning point in how these sheets were completed from a methodological point of view. Before that date, only some basic sections were required. The length, consistency and completeness of descriptions depended on the knowledge, curiosity and self-discipline of individual excavators, often without eliciting observations of interest from the point of view of this study. The improved form of the recording sheet introduced in 2004 required the specification of grave type and number of skeletons discerned in the fill. The recording of the information, especially for new trench supervisors, as well as its later reading, were facilitated by pictograms included on this form.

The present study has made use of data deposited in paper form at the PCMA UW Documentation Center, including Grave Register notebooks from the 1999–2005 seasons and 383 grave recording sheets from 1974–1984 and 271 sheets after that date (for a detailed enumeration see appendix to this chapter). The original documentation of the necropolis in Sector G, excavated in 1984–1986, which included grave recording sheets, drawings and excavation notes, constituted a separate group. It was published almost in its entirety; therefore, use of the unpublished documents from this set in the current study was reduced to establishing the covering of individual box graves. Information from archaeologist Emanuela Kulicka, inscribed in modified form in an MS Excel file (ALEX.S.A.059t), was treated as a separate source with the content of each entry being compared with that found in other kinds of sources. The author also had access to a copy of detailed and extensively illustrated excavation notes made by Barbara Tkaczow in 1977 when digging the necropolis in Sector W2.

Epigraphic analyses concerned funerary stelae, altogether 36 fragments dated paleographically and 12 bearing exact dates (see below, Table 5), which are crucial for establishing the chronological framework of the burial ground. Key data on the stelae, consisting of: inventory number, state of preservation, name and date of death of the commemorated individual (provided in the part of the text that could be read) are taken from published epigraphic and paleographic studies by Étienne Combe (1936) and Władysław B. Kubiak (1967b; 1975). Arabist Dorota Malarczyk has provided relevant information on the unpublished stela inscriptions, breaking however with her predecessors in that she refrains from a paleographic dating of the finds.

2.1.2 Synthetic studies and reports

Undertaking a study of the cemetery, the author already had a an extensive body of reports and synthetic studies, penned by the earlier excavators: Władysław B. Kubiak, Leszek Dąbrowski, Henryk Meyza and Wojciech Kołątaj, which presented and discussed the stratigraphy of the necropolis and its phasing (for a discussion of the tenets of this phasing, see below). Kubiak's observations were especially useful for understanding key issues for the previous division and dating of the necropolis. Kubiak (1967a) summarized the early excavations of the burial ground, setting the phases he distinguished within a broader historical context. Beside the division into the Lower and Upper Necropolis phases, already proposed by Dąbrowski (1966), he identified an intervening Middle Necropolis. Most of the conclusions presented in his study have not lost any of their timeliness. Kołątaj continued the work, publishing collective phased plans of graves from the area of the public baths (Kołątaj 1976). He proposed a more precise dating of the abandonment of the public bath complex on Kom el-Dikka and the first interments made in the late antique ruins.

The study of the Islamic cemetery on Kom el-Dikka was facilitated in particular by the exceptionally scrupulous excavations in Sectors G[3] and CS in 1985–1987. The work was meticulously documented and published as fully as was viable by a team of three researchers: Henryk Meyza (archaeologist), Grzegorz Majcherek (archaeologist, pottery specialist and later expedition director) and Henryk Rysiewski (anthropologist) (Meyza 2000; Rysiewski 2000; Rysiewski et al. 2000). It was accompanied by Barbara Tkaczow's summary of the discoveries in the necropolis up to that time and included plans presenting all the graves discovered previously in the Lower and Upper Necropolises (Tkaczow 2000). However, the scale of the drawings was too small to include grave numbers and it also caused the drawing of individual features to be greatly simplified.

In the context of the graves themselves one should mention a paper by Emanuela Kulicka, which is a well considered review of the typology of funerary structures found in the Kom el-Dikka cemetery, giving at the same time a summary of the state of research on the subject at the time (Kulicka 2011).

Interim reports (sometimes overlapping) were published in journals associated with the institutions directly involved in the work on the site; these have been listed here in the order of the number of reports appearing in each of them:

- *Polish Archaeology in the Mediterranean* (the largest number of reports, including the newest ones);
- *Études et Travaux* (through the late 1970s);
- *Bulletin de la Société Archéologique d'Alexandrie* (sporadic);
- *Annales du Service des Antiquités de l'Égypte* (sporadic).

[3] A measure of the thoroughness of these excavations is the large number of pit burials explored in the course of the project. In no other part of the site was a similar result obtained despite analogous deposition conditions and a similar density of stone features.

Anthropological studies, which will be discussed in detail in Chapter 3, were occasionally the only source of information on graves in a given part of the site, which were otherwise not mentioned in publications, as was the case with the graves from test trench B. Moreover, the accepted view of the division of the burial ground into three phases was first questioned and ultimately revised as a result of a detailed analysis of the anthropological sources (see below, *§ 2.3*).

2.1.3 Personal communication

Whenever certain determinations seemed essential, as in the case of verifying the nature of early inscriptions from the theater building (see below), personal communication and scholarly discussion with colleagues have been cited in lieu of actual publications. The author has also resorted to citing personal views and observations shared with him by other scholars whenever he could not refer to anything in print.

Apart from the issue of the inscriptions from the theater building, commented upon in private and in letter form by Dorota Malarczyk, the following four important issues were the subject of extended discussions with the individual scholars, providing grounds for the conclusions presented in this volume:

1) dating of the burial phases based on contextual archaeological material like coins, pottery and glasses; these finds proved to be of marginal significance for issues connected with the dating of the tombs (the validity of conclusions drawn from a review of the literature concerning these categories of finds has been confirmed personally to the author by Grzegorz Majcherek, the late Małgorzata Redlak and Renata Kucharczyk);
2) grave execution techniques, observing a noticeable improvement in stone-dressing proficiency among the makers of the Upper Necropolis graves compared to the outcome of the work of craftsmen building the Lower Necropolis box graves and Middle Necropolis superstructures (G. Majcherek, personal communication);
3) rate of aeolic accumulation; observations made by Majcherek near the auditoria indicate that wind-driven deposits accumulate today on the site at a rate of approximately 15 cm over the course of 10 years;
4) phasing, a key element of the current study, which argues in favor of combining the Lower and Middle phases into one (a proposition argued first by Majcherek).

2.2 Cultural markers

A cemetery in a city as cosmopolitan as Alexandria for most of its history (Abulafia 2014: 149–150; Haas 1997: 18, 44; Kucharczyk 2012: 37–38; Tkaczow 1988: 7), the Arab period included (Udovitch 2002: 99, 104), needs to be considered in terms of possible cultural markers that could identify the resident population. Religion and language, at least the one used by the population in official situations, are two fundamental markers of culture that can be represented in archaeological sources from historical periods. Islamic archaeology is still an underdeveloped field, as attested in the available literature, but in this context especially the archaeology of death suffers from the absence of a general synthesis. St John Simpson's "Death and burial in the Late Islamic

Near East: some insights from archaeology and ethnography" (1995), which is a chapter included in the volume *The Archaeology of Death in the Ancient Near East*, proved invaluable in searching for appropriate cultural markers in this case, as did a short chapter, "Death and burial", in Timothy Insoll's pioneering work, *The Archaeology of Islam* (1999). Also worth mentioning in the context of funerary customs is a book by Leor Halevi, *Rites for the Dead: funerals and the Afterlife in early Islam* (2007), the only one treating on emerging early traditions in this respect.

A typical Islamic burial in the early ages of Islam did not have a clearly defined character. It was the object of dispute among Islamic religious thinkers, the goal being to establish a model form of burial that would be distinct from that of non-Muslims. There is little in the medieval sources on the subject (Halevi 2007: 4–5), hence the need to resort to later practices. For the late Islamic burials there is much more data, allowing a preferred set of characteristics to be determined:

- **immediate burial** – the need for immediate burial is commonly accepted, although deviations from the rule are possible; exceptions were probably not frequent in practice (Insoll 1999: 168; Macklin 2004: 15);
- **body position** – set of characteristics including: position on the right side, facing Mecca (Insoll 1999: 168–169; Simpson 1995: 245), direct contact with the ground (Macklin 2004: 15) and depth sufficient to cover sexually important parts of the body, reaching the waist for a standing male and the shoulders for a woman (Simpson 1995: 242);
- **simplicity** – equality in the face of death, at least in theory; therefore graves of the rich and poor should be the same (Insoll 1999: 168);
- **single burial** – in principle, exceptions were permissible in case of war or epidemic (Simpson 1995: 242).

2.2.1 Evidence of cultural markers from the cemetery

The cultural identification of burials from the Lower Necropolis (the earliest phase) as Islamic was derived from the orientation of tomb structures regarding the cardinal points and body position. However, Christian grave structures could take on a similar east–west orientation and form, good examples being provided by the burials from Naqlun (Godlewski 2011: Fig. 7) and Karanis (Austin 2011: 48), both sites in nearby Fayum Oasis. The same can be said of burials in much more distant regions, such as, e.g., northern Jebel Ghaddar (Żurawski and Mahmoud El-Tayeb 1994: Fig. 3) in northern Sudan. In addition, the deviation from the east–west direction observed in tomb orientation on Kom el-Dikka, allowing the buried to rest their eyes directly on Mecca, coincides with the orientation of Roman-period architecture [*Fig. 9*], which was in all likelihood still to be observed aboveground when the first interments were made. Therefore, the positioning of burials in relation to the cardinal points cannot be taken as a decisive factor in determining cultural affiliation.

In the rare instances of a well preserved skeleton enabling detailed observation [*Fig. 5*], the bodies were laid on the right side, the head at the western end of the grave box (or pit) and facing southeast, in the direction of Mecca, the legs slightly bent at the knees (Dąbrowski 1966: 176). Skulls, often in fragments, that were found mixed with other bones at the western end of a grave box or pit and which Dąbrowski (1966: 176) had taken as evidence for the Islamic character of the burials—even ruling out other causes such as artificial skull relocation—could very well have belonged to individuals lying in supine position. This in turn could indicate the presence of

Fig. 5. Graves of the Lower Necropolis G-304 and G-308 with skeletons in anatomical order; view looking west

burials following a different rite. A mixed rite in the earliest phase of the cemetery on Kom el-Dikka is admissible at a time when conversion to Islam was an ongoing process and Christian members of the family of a fresh convert could have been buried in the same necropolis with him. The funeral and the form of the tomb, seen as a manifestation of the status and will of the family and not of the deceased (Pearson 1999: 73), could have created a situation in which burials, considered by modern researchers as Islamic from the point of view of membership of the deceased in a given social group, actually were not Islamic. However, in this case, in view of no recorded evidence of deviations from the model accepted as representing Islamic burial practices, one should accept as rather unlikely a massive presence of burials other than Islamic in this cemetery.

Therefore, the position of some of the skeletons remains the strongest argument in favor of an Islamic cultural affiliation of the oldest graves in this cemetery. There is nothing to counter this view, except perhaps the number of burials in individual graves, which in a few cases did not comply with the religious principle of a single deceased. Mass graves were accepted even though they were discouraged (Macklin 2004: 16). However, one cannot but notice the large numbers of burials made in the bulk of the graves from the Upper Necropolis. As will be argued below, the Islamic nature of this later burial ground is beyond doubt despite the common failure to comply with the said religious instruction.

All the stelae found at the site (Kubiak 1967b; 1975; Kowalska 1970) or in its immediate neighborhood (Combe 1936) were without exception inscribed in Arabic. The references to the Prophet in the text of these stelae are a clear indication of Islam. Adopting the two-phase chronological division of the cemetery (see below) and interpreting it within the dating frame proposed further on in this study (see below, *§ 2.4*), one should connect the earliest inscribed stelae found in the excavations with the Lower Necropolis.

The Islamic character of the Upper Necropolis phase of the cemetery is undisputed thanks to numerous examples of tombs with flat superstructures in the shape of a *mihrab* cast in relief in the plaster covering the stones (Kulicka 2011: 491) [*Figs 6; 25*]. In addition, the position of the bodies—on the right side, head in the southwestern end of a tomb, and turned to face Mecca—can be likened to the earlier phase, and the inscribed funerary stelae are all in Arabic, the inscriptions and decoration being either Islamic in nature or of undetermined religious affinity. Even so,

Fig. 6. Superstructures of the Upper Necropolis M-255 and M-266 with a *mihrab* design worked into the plaster covering the surface

similarly as in the case of the Lower Necropolis, one should provide for the possibility of a person professing a different faith having been buried here. While such situations are theoretically possible, at Kom el-Dikka they would have been most likely isolated instances.

In general, the graves on Kom el-Dikka did not yield any artifacts that could be connected with the inhumations (Kulicka 2011: 496). This followed the Muslim custom of not placing any goods in graves (Insoll 1999: 172). A few exceptions were noted from this rule, all of them from the Upper Necropolis: e.g., a coin that was intentionally put in the mouth of an individual from grave Q45, a ring found in AS143 (Kulicka 2011: 496), a bracelet adorning the leg of a woman buried in E47. However, most of the artifacts found in the cemetery layers could not be safely associated with any of the graves (Kulicka 2011: 496).

While the Islamic identification of the Upper Necropolis is not in doubt, there could have been sporadic burials of a different nature made in the area, especially after it had ceased to serve as a cemetery. There are the otherwise unexplained two graves with supine burials from an area near the Roman Bath, west of the late antique building. The plan [*Fig. 7*] shows two almost completely preserved skeletons in anatomical position, heads at the northeastern end of the grave pits and facing northwest. However, there is reason to consider this the effect of a drawing error at the stage of producing the plan for publication. Suffice it to turn the drawings around 180° and one gets a schematic picture of two burials that are in no way different from other earth burials found in this cemetery.

2.2.2 Cultural markers in context

Immediate burial is not something that could be identified in the archaeological material and yet it could have governed the form of tomb structures. The introduction of family tombs on Kom el-Dikka must have greatly facilitated new interments. The initial investment costs may have been relatively high and the time needed to construct a tomb relatively long, but the summary profit of the endeavor in light of the multiple burials in the Upper Necropolis, especially compared to the effort needed to build a single-burial grave box of the Lower Necropolis or even a simple earth pit, must have been considerable.

Body position followed religious principle. Skeletons discovered in anatomical order were invariably laid on their right side, legs bent slightly at the knees, head to the west, and facing in the direction of Mecca. The bottoms of the grave boxes did not have floors, ensuring direct contact with the ground, and the depth of the foundation (usually 1.20–1.50 m) was sufficient to provide proper treatment of both men and women. This reasonable depth, according to beliefs,

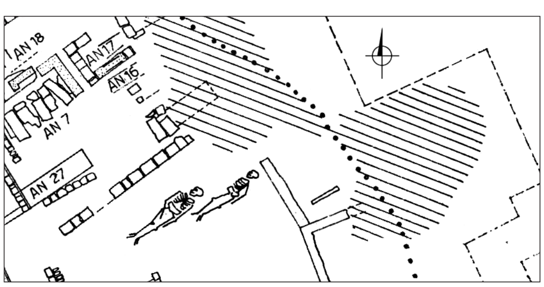

Fig. 7. Two graves of the Upper Necropolis with bodies laid supine on their backs; complete skeletons in anatomical order were shown on a section of the original plan (Kołątaj 1976: Pl. III)

allowed the deceased to sit up for interrogation by the angels on the first night after the burial. At the same time it allowed the dead to hear the call of the *muezzin* (Insoll 1999: 169; Simpson 1995: 242). In turn, other recommendations, like placing the feet first inside the grave (Macklin 2004: 15), were probably not obeyed, or not known, on Kom el-Dikka. The bulk of the tombs of the Upper Necropolis where this could be observed, were opened from the east, meaning that the corpses would have entered the boxes head first.

Simplicity was perhaps not the strongest point of the Kom el-Dikka Islamic graves. The absence of any furnishings corresponds with these dictates (Insoll 1999: 172; Simpson 1995: 245), but not the superstructures that were found here. According to the rules, burials should be of the simplest kind (Leisten 1990: 12–17) and there cannot be more earth in the superstructure than what was excavated from the grave pit. Neither should it be higher than a spread hand (Macklin 2004: 16). However, simplicity in its most ascetic form was probably the least respected prohibition in the Islamic world (Insoll 1999: 168). Superstructures and inscribed funerary stelae were probably a privilege for the elites. Costly and unreadable to the illiterate, they were beyond the means of the poorest (Halevi 2007: 16). From this point of view, even the modest superstructures of the Lower Necropolis would have been a manifestation of wealth. Moreover, the stelae mounted in the structure of these early tombs sometimes appeared above the feet on the eastern side (Kulicka 2011: 485) and not, as they should, at the western end above the head of the deceased (Insoll 1999: 169). Inscriptions and richly decorated tomb markers are disapproved of in Islam (Simpson 1995: 247). Hence, the *mihrab*-shaped hollows in the superstructures of the Upper Necropolis may be perceived as a further deviation from the initial severity of form. Since the role of the superstructure was to protect the burial from being disturbed (Macklin 2004: 16), any decoration or inscriptions on it were superfluous.

Multiple burials were permitted in Islam only in war or during an epidemic (Simpson 1995: 242). In light of this, the change from the Lower Necropolis with its mainly singular burials to the collective burials common in the case of the Upper Necropolis, with most probably family tombs of up to a dozen or so individuals, seems meaningful. Men, women and children were buried together in one grave, a fact that needs to be addressed in view of the rule for separating the sexes (Insoll 1999: 172). Moreover, successive inhumations in these tombs almost always disturbed the earlier burials. It would thus be the third rule, that of not disturbing the burials (Insoll 1999: 169), that was broken in the case of the burial practices in the Upper Necropolis. The changes are understandable in the context of a presumed population growth in Alexandria at the beginning of the reign of the Fatimids, which would have translated directly into a greater demand for burial places. Land covered by the graves could have grown exponentially and there could have been a multiple increase in the number of people buried on Kom el-Dikka in the Upper Necropolis phase compared to the situation noted for the Lower Necropolis. In times of considerable growth and prosperity, ensuring enough space for single pit burials and grave boxes intended for one would have meant resignation of a probably prestigious funeral within the city walls or the repeated destruction of already existing tombs. In this sense, multiple-burial structures can be viewed as a reasonable compromise.

Observations from other regions of the Islamic world indicate that children, who are sinless, were seldom buried in the same cemetery with the adults. Instead, there are separate regions or even whole cemeteries created just for them (Simpson 1995: 244). Child burials on Kom el-Dikka were located among the bodies of adults and while small box structures were built exclusively for children, their numbers were actually few. At the much later cemetery at Quseir al-Qadim (from the 14th–15th centuries), child skeletons lay between adults of different sexes, as if separating them from one another (Macklin 2004: 16). No similar practices were noted on Kom el-Dikka.

2.2.3 Evolution of the burial ground

The Islamic cemetery on Kom el-Dikka started with graves intended in general for single burials that, although modest in form, provided good protection for the body, the tomb markers on the ground being equally modest. It generally followed identifiable religious principles, but the direction taken by its subsequent evolution appears to have been less than orthodox. The tombs of the Upper Necropolis with their more elaborate grave boxes intended for multiple burials and the decorated superstructures combine Islamic simplicity with a return to the ancient or to put it more broadly, Mediterranean tradition, forming in effect much larger and more artistically accomplished family sepulchers.

The localization of the cemetery is in the same spirit. Burial inside the city walls was seldom practiced in Islam (Simpson 1995: 243), but in the late 8th century when the first burials were being made, the ancient fortifications were in ruins and the inhabited area lay more or less south and east of the location of today's archaeological site. The new city walls built here in the mid 9th century left the burial ground inside the circuit, hence its continued functioning within seems only natural. It is also possible that the administration of Alexandria at the time, for the most part Christian, saw nothing untoward in the location of graves within the city boundaries. After all, the dead were buried inside the ancient city of Alexandria long before the Arab conquest.

2.3 Revised cemetery phasing

The Islamic cemetery on Kom el-Dikka, which covers and sometimes cuts into ancient layers, is not a one-time foundation restricted to a strictly defined moment in time. Its development and the chronology of particular phases continues to be debated despite half a century of archaeological excavation and research [*Table 1*]. Current ideas concerning the phasing of this cemetery introduce chronological divisions into two (Dąbrowski 1966) or three (Kubiak 1967a) main phases of burial practices in this spot. Both are justified depending on the sector of the site considered and the assumed level of detail. Contrary to expectations, the picture emerging from a study of the stratigraphy of the cemetery area is fragmented into a number of views, each of which is true when considered in a local dimension. The division of the necropolis into three general phases: Upper, Middle and Lower (Kulicka 2011: 498), proposed by Władysław Kubiak (1967a), is generally accepted by researchers studying the site and has never been seriously questioned in the absence of a clear stratigraphy in the depositions containing cemetery layers. Part of its success lies in the simplicity of its application to current fieldwork. The most recent approach to the division (Meyza 2000) introduced two additional transitional phases, but generally confirmed the existing scheme.

Table 1. Phasing the necropolis at Kom el-Dikka, a historical overview; location of sectors indicated in *Fig. 8*

L. Dąbrowski (1966)		W.B. Kubiak (1967a)		H. Meyza (2000)		R. Mahler	
Sector A		Sector C		Sector G		Combined data	
Phase	**Century**	**Phase**	**Century**	**Phase**	**Century***	**Phase**	**Century**
Upper	16th–18th	Upper	11th–12th	Upper	11th–12th	Upper	11th–12th
				Upper/Middle			
Lower	13th	Middle	9th–10th	Middle	9th–10th	Lower	9th–10th
				Lower/Middle			
		Lower	7th–8th	Lower	7th–8th		

* Dating: Majcherek 2007b: 22; Majcherek and Kucharczyk 2014: 25

In light of this, a review of the situation would seem like a wasted effort were it not for the fact that the non-standard results generated for the age-at-death analysis of individuals buried in a three-phase cemetery (see below for a detailed discussion of the issue) are incongruous with it. Reasons for this state of affairs may have been found elsewhere, but discussions with Majcherek brought to the author's attention the possibility of a different explanation deriving from a revision of the premises which the current working chronological division of this cemetery is based on.

The absence of a clear-cut division in the stratigraphic record between the Middle and Lower Necropolises is evident to anyone studying the mutual stratigraphic relations of the two presumed phases (Meyza 2000). But where stratigraphy fails, secondary and even tertiary observations have to take over. An overall analysis of the material confirms the rationale behind considering these two phases, Lower and Middle, as one. In effect, we would be dealing with just two general phases of use of the cemetery, and the so-called Middle Necropolis would in all likelihood be an integral part of the Lower Necropolis.

A key argument in this respect is the cultural transformation model that is reflected in the evolution of the tomb form. This, in turn, can be reduced to the following set of simple features describing in general the three phases of the division:

Lower Necropolis — stone grave box and no tomb marker;

Middle Necropolis — no grave box (pit burials exclusively) and a simple tomb superstructure taking on the form of a rectangular stone enclosure furnished with a stone stela;

Upper Necropolis — stone grave box and superstructure (relatively rich set of forms).

Assuming this chronological sequence of the transformation, one is faced with the need to explain the disappearance of grave boxes at the onset of the Middle Necropolis phase and their return in the Upper Necropolis phase. It is highly improbable that cultural change, somehow reflected in the form of a tomb, would have opted for discontinuity beyond that manifested by evolutionary change in this aspect. Seeing no violent cultural change in the period in question, the manner in which people of medieval Alexandria treated their dead would have been subjected to gradual and

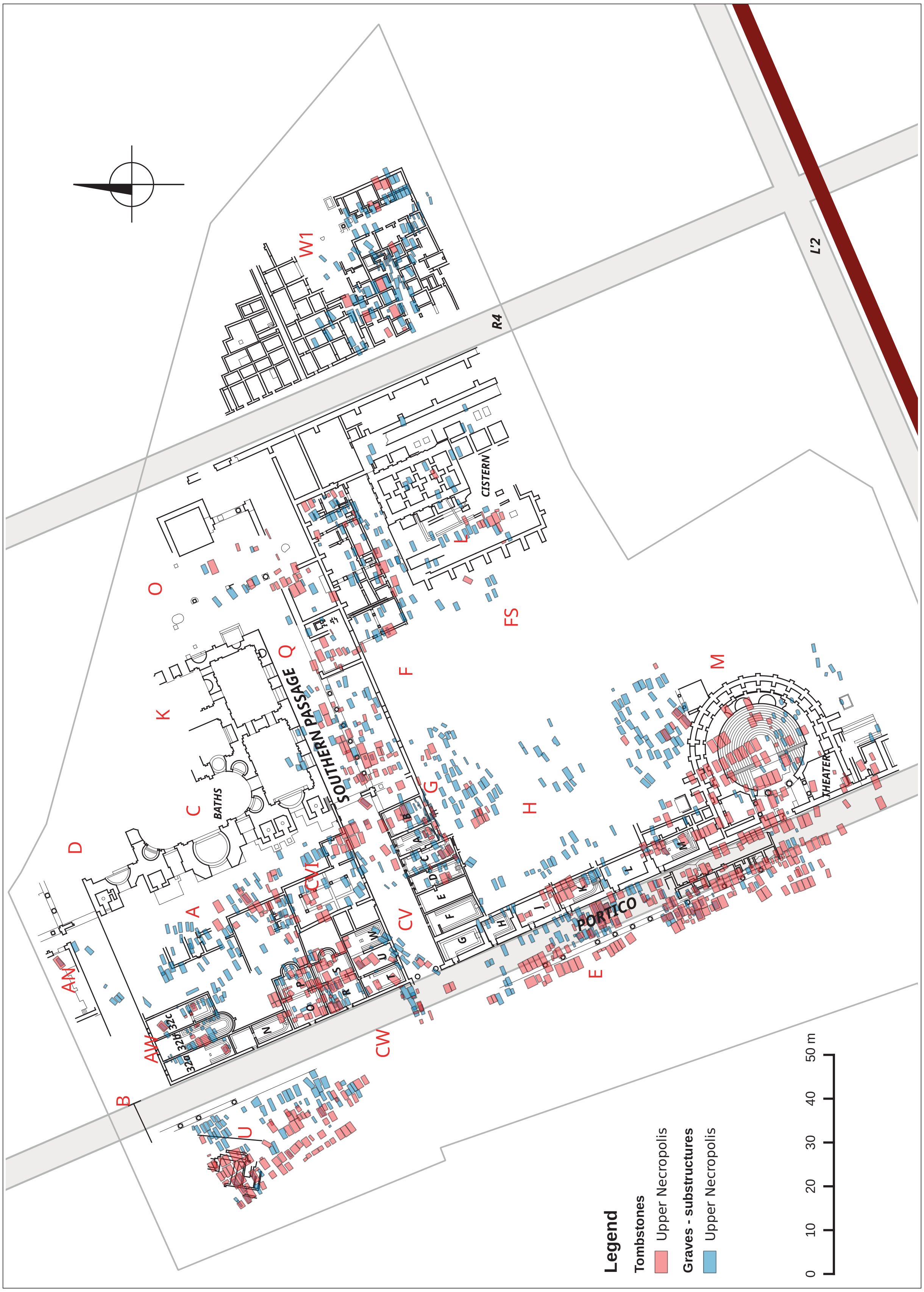

Fig. 8. Grave structures of the Upper Necropolis; sectors marked with letter designations

Fig. 9. Grave structures of the Middle and Lower Necropoleis; sectors marked with letter designations

directed transformation[4] rather than any major turnabouts. In this approach, the idea of a Middle Necropolis becomes like a foreign body, artificially forced in between the Lower and Upper phases of the cemetery.

The said inconsistencies disappear when the cemetery is considered as a two-phase unit. The Middle Necropolis fills the gap between the Lower and Upper phases, furnishing the Lower phase with the hitherto missing grave superstructures and itself being furnished with the stone grave boxes that it had been deprived of in the three-phase division. Having linked conceptually the grave boxes of the Lower Necropolis with the superstructures of the Middle Necropolis, we are now dealing with two phases of almost identical description:

Lower Necropolis stone grave box and simple superstructure,
Upper Necropolis stone grave box and superstructure.

This hybrid structure matching a modified lower-phase characteristic emerges in the earlier interpretation of the exploration of Area G, where, at least in the drawing [*Fig. 10*], a tomb superstructure assigned to the Middle Necropolis coincides within the same chronological horizon with two stone grave boxes perfectly fitted into the outline of the superstructure. From a typological point of view, G-25 and G-36 are practically typical Lower Necropolis structures (the sole difference is an additional row of stones in the box casing), but in terms of the stratigraphic column, they are assigned to the transition between the Middle and Upper phases of the cemetery (Meyza 2000: Fig. 17). Each of these features, although evidently of Middle Necropolis attribution according to the responsible researcher (Meyza 2000: Pl. V), was dealt with as a separate grave and given a separate number. However, one cannot escape the impression that superstructure G-47 and grave boxes G-25 and G-36 together form a single tomb (Meyza 2000: 39), the vertical distance between the stone slabs covering the actual burial and the tomb marker being almost one meter. Interestingly, the excavation conducted in the 1980s in Area G did not bring to light any stone structures that could have been identified as belonging to the Lower Necropolis (Meyza 2000).

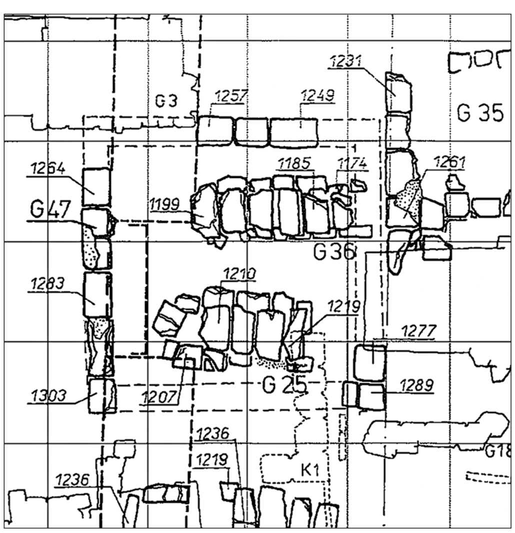

Fig. 10. Graves of the Middle Necropolis: superstructure G-47 and two grave boxes G-25 and G-36 (Meyza 2000: Pl. V)

[4] This line of reasoning is supported by the general concept of continuity of ideas within a culture (Johnson 2010: 63).

The highly simplified description presented here does not take into account the pit graves proliferating all over the site in all phases. It also does not consider several other important features, like due diligence in the making of the graves and the required expenditure of labor, because a consideration of such factors at this rudimentary level of the analysis would have surely diluted the essence of the question.

The argument in favor of the two-phase division will be discussed below in detail, but the need for continuity of cultural models in the case of the chronological division of the cemetery under discussion, at least on a very basic level, stands strongly in favor of a shift to a two-phase chronological division and the abandonment of the three-phase solution. It means that for all practical purposes the Lower and Middle Necropolises will now be considered as the earlier of the two phases of the cemetery on Kom el-Dikka, while the Upper Necropolis remains unchanged as the second identified phase in the functioning of the burial ground. Fundamentally, the cons do not outweigh the pros, because while there is nothing conclusive in the stratigraphy in favor of the presented reasoning, the examination of the excavation results shows nothing evidently in contradiction to it. It was not possible to discern in the material any relations that could have swung the interpretation either way, and the reconstruction of the processes developing over time based on the observed relations was on a rather general level.

2.3.1 The argument for the two-phase division

The tomb superstructures of the Middle Necropolis in the three-phase division scheme consisted of simple rectangular enclosures made of limestone blocks, sometimes incorporating a stela [*Fig. 11*]. More often than not, they surrounded an area bigger than a substructure intended for a single burial would lead one to expect. Indeed, in many cases they were sufficiently wide to encompass even two grave boxes of the Lower Necropolis [see *Fig. 10*]. In some instances they match up with the grave boxes lying under them, in others they clearly miss.

The failure of direct superposition would be explainable, if the superstructures were constructed sometimes long after the burial, hence without direct observation of the location of the grave pits. Then the fact that the enclosures do not line up with the grave boxes need not be construed as evidence of there being no link between the two. The practice of multiple burials and the long existence of the cemetery gives a fairly reasonable picture of continuous dismantling and reconstruction of superstructures despite the separateness of the underground parts of a grave. Adding to this a rising ground level resulting equally from aeolic build-up of sediments (the most intensive where obstacles existed), the accruing of rubble from deteriorating ancient ruins in the neighborhood, and the accumulation of deposits connected with the construction of new burials, one can reconstruct a process of constant rebuilding of the superstructures at ever rising levels. A good example of this process comes from the northern part of sector E where successive levels of tomb superstructures were superposed [*Fig. 12*].

The vertical distancing between the successively rebuilt or newly constructed superstructures and the first underlying grave substructures of the earlier of the two phases of the cemetery grew over time. The latest superstructures in the series may have been raised already at a time when there was no connection between them and the earliest subterranean structures beneath. The Middle Necropolis superstructures in auditorium G are a good example, separated from the top

Fig. 11. Superstructures of the Middle Necropolis with the steles

Fig. 12. Superposed tomb superstructures of the Middle Necropolis

of the burials in the floor of the auditorium [see *Fig. 5*] by approximately 1.50 m. Tomb marker G-201 and grave box G-308 were situated at, respectively, 10.39 m asl and 8.77 m asl. Assuming the anticipated quicker accumulation of deposits inside the ruined interiors of late antique buildings (debris and drifted dirt would have piled up against the walls, which were additionally rain-washed of eroded fragments and accumulating dirt) as opposed to the open portico and especially the open square west of the portico (McKenzie 2007: 72), one could easily explain the greater differences in the foundation levels of the grave boxes and superstructures observed within the walls of the lecture halls. Kulicka (2011: 485) found this difference to amount to 3 m in places. However, the database evidence and the plan generated for the purpose of this study do not reveal any differences of this magnitude (unless it is a case of missing data).

Simple earth burials found under some of the superstructures could represent either a direct connection with the marker or a later "addition", intentionally connected or not. The lack of clarity in this respect is due to extensive disturbance of individual contexts and the resulting poor visibility of small earth features in the excavation. A direct connection was possible, if the burial was earlier, but a later connection, if the burial was added to the already existing superstructure, cannot be ruled out. The situation of the grave pits, regardless of the potential scenario, does not stand in contradiction to the statement that the superstructures of the Middle Necropolis are actually part of the phase identified as corresponding to the grave boxes of the Lower Necropolis.

The vertical relations between the two are also not in any contradiction. In most cases, the differences between the situation in the vertical plane of the Lower Necropolis grave boxes and the superstructures of the so-called Middle Necropolis oscillate around the values noted for the complete tombs of the Upper Necropolis. It should be kept in mind that the timeframe for the formation of the two phases (assuming a two-phase division) is sufficiently broad for the earliest burials in this place to be disturbed repeatedly by later interments, a fact exemplified repeatedly in the archaeological material from the cemetery (Meyza 2000). As said already, the superstructures of the Middle Necropolis could have been dismantled repeatedly for the same reasons. The relatively simple structures offered no obstacles in this respect and, if neglected, easily disappeared from view under drifting sand in a matter of a couple years. A new burial, possibly a simple earth pit, could have easily been located in such a plot, together with a superstructure built already on a higher level.

A greater chronological resolution of the first phase of the cemetery, composed thus of the combined Lower and Middle Necropolises, does not appear possible in light of the above considerations. In a few cases, a limited resolution is tenable. Meyza's stratigraphic observations (2000) or the typological differentiation of superstructures of the Middle Necropolis noted by Kulicka (2011: 485–488) are an excellent example, and Kulicka observed that the older superstructures had stelae fixed on the western side of the rectangle and the younger ones on the eastern side [see *Fig. 12*]. Nonetheless, the tombs appear to be nearly contemporaneous, as illustrated also by graves E-146 and E-145, where the later E-145 was founded directly on top of an earlier superstructure, using the small blocks from the enclosure of E-146 as a "foundation" for the later structure (Kulicka 2011: 486, 488). However, the few cases that were observed do not constitute a sufficient base for generalized conclusions concerning the burial ground as a whole.

The merging of the Lower and Middle Necropolis phases also explains the absence of any evidence for a walking level associated with the graves of the Lower Necropolis. Such walking levels were easily established for the Middle and Upper cemeteries owing to the presence of superstructures.

Atypical tombs from both phases have been observed in two places in the excavated area. One of these are the superstructures of Lower Necropolis tombs in Sectors CV and CW near the portico, located in two units east of Locus W, which were misleadingly like their counterparts from the Upper Necropolis in appearance. One of them, CV-7, was even shaped like a *mihrab*, a form of decoration typifying the most ornamental of the later tomb markers (see below, *§ 2.5*). Either there were never any tombs of the Upper Necropolis in this place as well as to the south of it, inside the portico, or the tombs designated stratigraphically as belonging to the (now) Lower Necropolis were mistakenly assigned to this phase during exploration and should actually be considered as belonging to the younger phase. In turn, atypical Upper Necropolis tombs with barrel vaults were located west of the entrance to the Southern Portico and right next door was a section of tombs with a distinctly different alignment [see *Fig. 26, 27*]. Perhaps burial activities in this area lasted the longest and the phases *de facto* passed smoothly from one to the next.

2.3.2 Division between phases and the 'earthquake-of-796' dating quandary

Considering stone structures only, the recorded stratigraphy indicates a clear division between two cemetery phases (Dąbrowski 1966: 176), much less so when the three-phase division is applied (Meyza 2000: 38, 40, 42), despite the clear differences explicated by Kubiak in his report from

Sector C, where the three-phase theory was first introduced.[5] The substructures of the Upper Necropolis are separated from those of the Lower phase by layers of urban rubbish (Dąbrowski 1966: 176); in addition, the level of the foundation and the structural form point to clear differences between the phases [*Fig. 14*]. The grave boxes of the Upper Necropolis were on a level corresponding to neighboring superstructures of the Middle Necropolis (now renamed as the Lower Necropolis) [*Figs 13; 16*], which they damaged, reusing the stone blocks and stelae in their construction. The differences between superstructures of the Lower (formerly referred to as the Middle Necropolis) and Upper phases were again distinct, in terms of the level of founding as well as form.[6] Even taking into account the rubbish-dumping character of the accumulated layers between the two phases, that is, the possibility of accelerated and uneven accumulation depending on the location within the territory of the vast burial ground, the time that needed to pass between the last burials of one phase and the first ones of the next phase should be counted in dozens of years, perhaps even a hundred.

With regard to the substructures of the Lower Necropolis and the Middle Necropolis (according to the three-phase division) superstructures, at least in the areas where the latter have been preserved, it is difficult to note such distinct differences. Comparing the form of a grave box to the form of a superstructure does not seem a viable option, whereas the differences in the level of founding between the two, when considered in the light of the easily measured values for the Upper Necropolis, oscillating at about 1.00–1.50 m, point to a possible link between them. Moreover, as demonstrated by the example discussed above of the grave boxes G-25 and G-36 from the Middle Necropolis (Meyza 2000), a direct connection with superstructure G-47 appeared plausible [*Figs 10; 15*], even if, due to soil conditions, the outlines of pits made for successive burials could not be traced in the ground before the excavation of the burial (Meyza 2000: 35, 38). This made it impossible to establish conclusively relations between structures that were not directly connected, and such difficulties were encountered practically in all parts of the site in question.

In the case of the first burials on Kom el-Dikka, the collapse of the late antique columns was of fundamental importance for the dating of the former division of this early necropolis into two separate phases and this introduces the earthquake dating quandary that resulted in early confusion with the dating of the first phase of the necropolis.

Violent natural events are of considerable help for archaeological periodization on sites in the Mediterranean as a whole. They affect large populations, leaving a mark not only in the living memory. Whole cities could be ruined and rebuilt, states could fail and civilizations could fall, but most of all, such events were chronicled (Abulafia 2014: 27–28, 45, 438; Marco 2008; Ambraseys 2006; Badawy 1999). Wojciech Kołątaj concluded in his study (1976: 223) that there was one major seismic event in Alexandria between the end of the 4th and the 14th century, and attributed

[5] Walls of the late antique academy complex discovered approximately 1.50 m below the substructures of tombs of the Upper Necropolis were initially interpreted as remains of Arab-phase architecture (Kubiak 1967a: 52; Lipińska and Riad 1966: 103–105). Extensive remains of the pavement in the Bath Portico, between trenches G and CIV, were also assigned to this historical period. The graves that were discovered below the pavement (Kubiak 1967a: 54) were considered by the excavator as older than the pavement, dating to the early years after the Arab conquest. These early interpretations were quickly proved wrong, but never corrected, presumably because of the obvious nature of these mistakes, which is clear, however, only from the perspective of further research.

[6] Except for a few cases from the western parts of the Bath Portico and the graves in the immediate vicinity where superstructures of the Lower Necropolis took on a form known from the Upper Necropolis.

Fig. 13. Stratigraphic relations between the tombs of the Lower, Middle and Upper Necropoleis as observed in the portico south of the baths. Letters indicate structures: A – Lower Necropolis, B – Middle Necropolis, C – grave box of the Upper Necropolis, D – superstructure belonging to the Upper Necropolis grave box, E – toppled column (letter marking based on a published illustration; see Kołątaj 1976: Fig. 4)

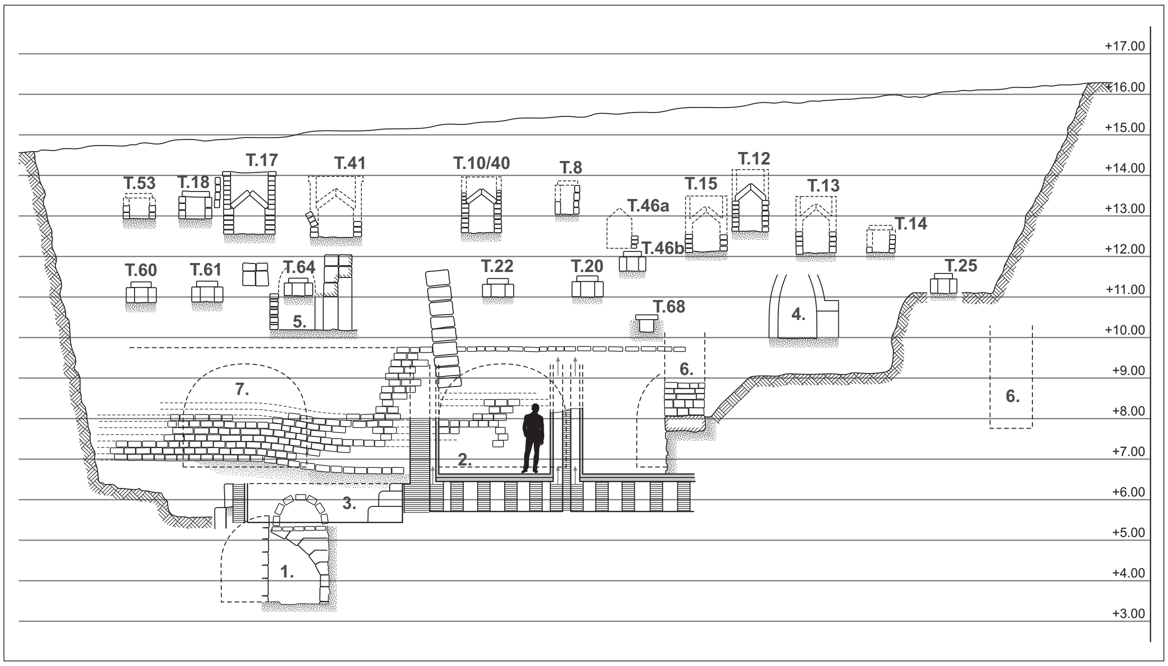

Fig. 14. The north–south section in test Trench A, showing only the grave boxes of the Upper Necropolis (T.53, T.18, T.17, T.41, T.10/40, T.8, T.46a, T.15, T.12, T.13, T.14) and the Lower Necropolis (T.60, T.61, T.64, T.22, T.20, T.46b, T.68, T.25) (Dąbrowski 1966: Fig. IV)

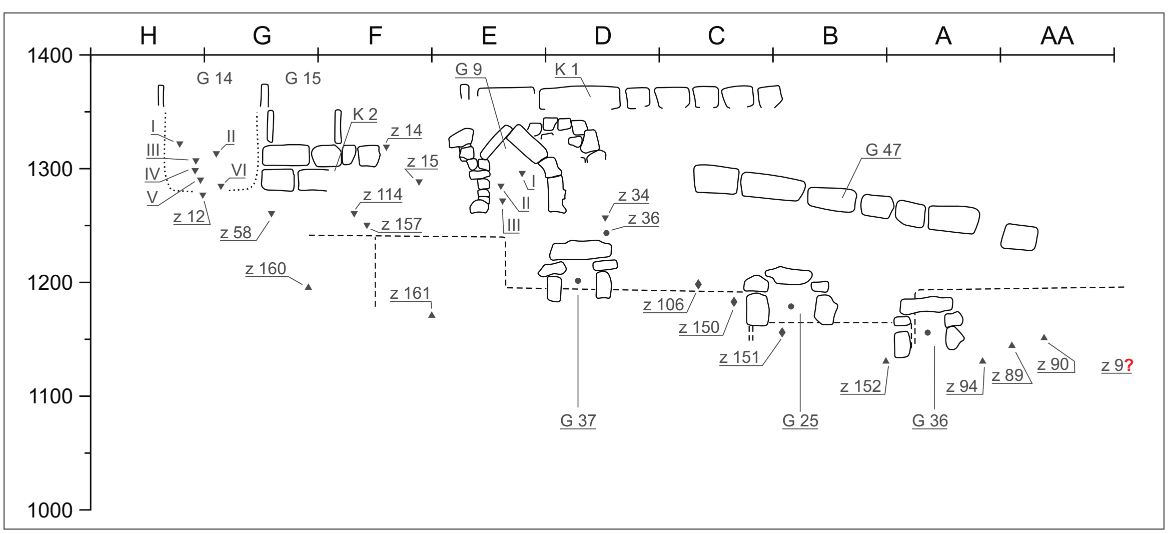

Fig. 15. The south–north section in Sector G, highlighting the relations between the grave boxes of the Upper Necropolis (G-9, G-14 and G-15) and the grave boxes and superstructures of the Middle Necropolis (G-37 and G-25, G-36 and G-47) (After Meyza 2000: Fig. 16)

Fig. 16. Collapsed columns of the so-called Theatre Portico in between and under the substructures of the Upper Necropolis and superstructures of the Middle Necropolis

to this quake of 792 most of the serious damage to the ancient buildings on Kom el-Dikka. At the same time he also admitted the possibility of a deliberate toppling of the columns in the portico (Kołątaj and Kołątaj 1975: 95; Kołątaj 1976: 223). The role assigned by many researchers to this cataclysmic event from the end of the 8th century most likely draws upon the written sources, according to which the uppermost tier of the Alexandrian lighthouse was destroyed at the time (Kubiak and Makowiecka 1973: 123; Taher 1998: 52; Badawy 1999: 125).

Recent research has demonstrated multiple episodes of this kind within the period in question. A list compiled by Ahmed Badawy (1999: Table 1) includes at least five other no less severe earthquakes in the period from the Arab conquest to the 11th century, the age of Fatimid rule in Egypt, which is probably the time horizon of the Upper Necropolis. All of them may have caused destruction within the city [*Table 2*]. The monumental late antique architecture on Kom el-Dikka need not have suffered in most of these events, considering that nothing less than an earthquake of 8-degree magnitude in the Modified Mercalli Intensity Scale could overturn columns and bring down solid buildings (Wood and Neumann 1931).

In this context, the quake of 796 with 7-degree magnitude should not have endangered the structure of the late antique portico. However, considering the difficulties of estimating the magnitude of a seismic event in the past from a modern perspective and the general structural deterioration of ruined ancient buildings over time, we may assume with all due reservations that a magnitude 7 quake on Badawy's list could have also caused the columns to collapse. This is hugely important for dating some of the grave structures which have been found in stratigraphic relation to the toppled columns [*Fig. 13*].

The destruction of a given tomb structure by a falling column does not mean that it occurred during the first seismic episode that had the potential to topple it. Since most of the early excavators knew of the existence of only the late 8th century quake [*Table 2*: No. 4], there must have been confusion when superstructures of the Lower Necropolis, interpreted back then as belonging to the Middle Necropolis, were suddenly found damaged or below lying columns [see *Fig. 13*]. These superstructures were dated to the 9th–10th century by the dates on the stelae and therefore reached into the future far beyond the quake of the late 8th century. To address the issue, it was assumed that the columns had toppled on the earliest superstructures of what was interpreted as the Middle Necropolis. Therefore, excavators came to the conclusion that substructures of the Lower Necropolis must have been of earlier date. They also concluded that a cemetery of this size could not have accrued in this spot over a short period of time, and consequently pushed back the time of the first graves on the spot to the period of the Arab conquest of Egypt (for the chronological framework of the cemeteries, see below, *§ 2.4*).

Once the division into the Lower and Middle Necropolises is seen as artificial, the fallen columns between and below the grave boxes of the Upper Necropolis and the superstructures of the Lower Necropolis [*Fig. 16*] can be treated as markers determining the rather imminent end of the latter. In this context, the earthquake of 796 is hypothetically the caesura for the end of Antiquity on this spot, after which the funerary function of this part of the city became predominant. Naturally, loss of function is not tantamount to the leveling of every last piece of ancient architecture that was still standing aboveground in this area.

Successive quakes of similar magnitude, recorded in the sources for the years 885, 912, 935 [*Table 2*: Nos 7, 8 and 9, respectively] must have added to the destruction. Hence the columns lying on top of graves belonging to the Lower Necropolis should be interpreted as still standing

Table 2. Earthquakes in Egypt. MMI signifies earthquake magnitude in the Modified Mercalli Intensity scale (Badawy 1999: Table 1)

No.	Date (CE)	Latitude	Longitude	MMI	Felt at:
1	14 October 520	31.00	30.00	VII	Northern Egypt
2	553	32.00	29.70	VII	Alexandria
3	742	29.50	33.00	VI	Gulf of Suez
4	14 April 796	31.20	29.50	VII	Alexandria
5	857	30.00	31.20	V	Egypt
6	27 January 859	30.50	31.50	VI	Bilbais (Egypt)
7	3 November 885	30.10	31.20	VII	Northern Egypt
8	912	30.00	31.00	VII	Egypt
9	4 October 935	30.50	31.20	VIII	Northern Egypt
10	25 July 950	30.20	31.20	VI	Northern Egypt
11	15 September 951	32.00	29.00	VII	Alexandria
12	1 January 956	32.00	30.00	VIII	Eastern Mediterranean
13	967	26.50	32.50	V	Southern Egypt

until at least 796, although they could well have stood for quite a while longer. Moreover, different graves could have been crushed by falling architectural elements at different times, in the course of seismic episodes quite distant in time. The next two quakes, in 951 and 956 [*Table 2*: Nos 11 and 12], occurred within five years time from one another. The first was of a 7 magnitude and caused serious damage to the structure of the Alexandrian lighthouse.[7] It is said that the cataclysm also had the effect of opening many new springs of water inside the city. Nothing is known of the damage caused in Alexandria by the second of these two events, estimated to have had a magnitude of 8. It was felt in Cairo, although it caused no destruction there (Badawy 1999: 126).[8] It is possible that the two quakes remodeled life in 10th century Alexandria and because of this they may be considered as the border date for the ultimate abandonment of the Lower Necropolis.

2.3.3 The age-at-death quandary

Human remains, or to be more precise the age-at-death frequencies of the buried population for the different phases of the cemetery, are discussed in detail in the bioarchaeological part of this study (see *§ 3.3.4* and *§ 3.4.2*). However, the age-at-death analysis was the only one of the initial analyses of the material that raised any doubts, leading the author to consider in all seriousness a suggestion made by Majcherek (personal communication) that a presumably faulty phasing of the cemetery finds could be at the root of the problem. This ultimately led to a review of the chronological phasing of the cemetery and the herein proposed two-phase division. In view of this, it is in order here to take a closer look at the age-at-death frequency in the light of the old three-phase division.

Age-at-death data illustrate the frequency of different age-at-death categories among the adult population from the cemetery. Broken down by the three-phase periodization of the burial ground, the interpretation of the series from the Middle Necropolis gave a result that differed considerably from the model for skeletal populations known from other sources, that is, a classical population pyramid (Chamberlain 2006: 16; Keilman 2010: 26). The two series from the Lower and Upper Necropolises fit into the generally expected frame, showing as anticipated a relatively high percentage of child deaths, a distinctly lower, although still high share of deaths in early adulthood, and dropping numbers for mature and old age.[9] For the Middle Necropolis, the value of this parameter for the mature age group was exceptionally high, resulting in a frequency distribution for the Middle Necropolis that clearly differed from the standard [*Fig. 17*].

[7] Mohamed A. Taher (1998: 53) placed the first of the two earthquakes in the second half of 950 and, unlike Badawy (1999: 126), considered the second one, in 956, as the one that was responsible for damaging the lighthouse structure.

[8] Badawy (1999: 126) is of the opinion that the lighthouse was completely destroyed in 951, while others have cited 956 as the year of its partial destruction (Taher 1998: 53) or else consider that it was restored in 980 and collapsed in the early 11th century, after which only the lowest part continued to be functional (Tkaczow 1988: 159). The latter interpretation, at least with regard to the damage wrought by the cataclysm, is all the more probable when one recalls the report of the historian al-Balawi who saw it still standing in 1165 (Sanders 1998: 167). Badawy (1999: 127) writes of recurrent damage to the lighthouse in 1303, whereas Tkaczow (1993: 47) is of the opinion that 1303 was the year when the building was ultimately destroyed.

[9] For greater readability in the discussion of the age of the deceased, intuitive descriptors have been applied: "old" refers to a biological age evaluation at 55+, "mature" to 35–55, "young adult" to 20–35, "adolescent" to 14–20, "late child" to 7–14 and "young child" to 0–7. The overlapping of the age brackets emphasizes their biological rather than chronological nature.

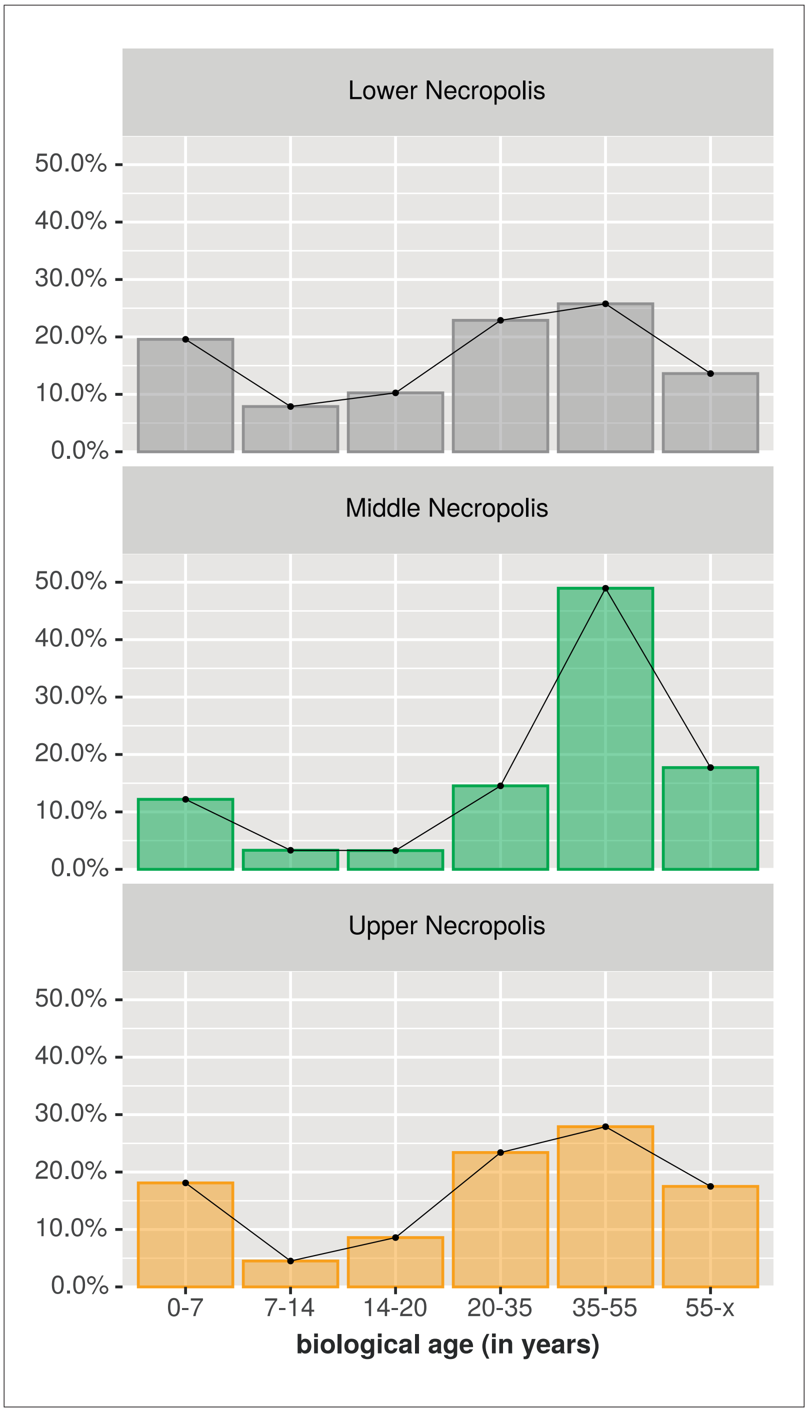

Fig. 17. Percentage share of particular age-at-death groups among the individuals buried on Kom el-Dikka, subdivided into three chronological phases

Comparing the results with data from demographic research, one needs to keep in mind the difference between chronological and biological age. Biological age, which is determined as a result of osteological analysis, is an evaluation of the development stage or "use-wear", so to speak, of an organism in the context of the developmental changes at different stages of the human life. The resolution of these evaluations, that is, their ability to reflect a specific point in ontogenesis, is not uniform and generally diminishes as an individual gets older. The specificity of working with archaeological material, which is often incomplete, eroded and/or disturbed, additionally clouds the issue. Hence age ranges that do not match the usually five-year intervals used in demographic studies. The developmental age ranges in osteology are so uneven that taken together, the first three brackets (0–7, 7–14, 14–20) cover the same number of years of life as the fifth bracket (35–55), which is, in turn, smaller by more than a half than the sixth (55–x), if 100 years is the assumed arbitrary upper limit (discussed *in extenso* below, see *§ 3.3.4*).

The described inconvenience when comparing skeletal age-at-death group frequencies with data from demography does not influence comparisons made according to the same methodology. The higher frequency for the 35–55 years group (48.95%) for the Middle Necropolis [*Fig. 17; Table 3*] was almost twice as high as the respective values for the Lower (25.77%) and Upper (27.90%) phases. Frequencies considered in combination with the sex of the deceased [*Fig. 18*; *Table 4*] show interesting changes for the Lower and Upper Necropolises, but do not throw new light on the anomaly observed for the Middle Necropolis. In this case, the observed values could be explained by a number of rational factors, like sudden population change, cultural preferences in the choice of burial sites, not to mention faulty age determination. The simplest explanation, however, was an error in the chronological periodization of the cemetery. It should be noted that the anomaly did not disappear completely once the data for the Lower and Middle Necropolises was merged [see below, *Fig. 32*]. It points to its strength, suggesting the need for further analysis.

The relatively low percentage of child burials for the Middle Necropolis was also puzzling. It also argued in favor of a faulty chronological division of the burials in the cemetery. It was almost half as high for the Middle Necropolis (18.78%) as for both the Lower (37.72%) and Upper (31.21%) phases [see *Table 3*]. To some extent it could be explained by the nature of the subterranean features attributed to the Middle Necropolis phase, which were almost without exception simple grave pits;[10] burials inside stone substructures predominated in the other two phases. The much lower share of identified child burials in the analyzed set may have resulted from the demonstrably poorer state of preservation of skeletons in earth burials and the considerably greater difficulty of observing the small and severely eroded bones of children in the archaeological layers, especially if not accompanying an adult burial. However, considering that the extremely thorough exploration in Sector G[11] yielded an even lower share in the case of the Middle Necropolis (not quite 10%), as opposed to the site as a whole in this phase (almost 20%), the form of burial could not explain everything. Once the Middle Necropolis data was added to the figures for the Lower Necropolis, the percentage of child skeletons for the new joint phase thus created rose to 30.72% [see below, *Table 21*], which is almost identical to the analogous value for the Upper Necropolis (31.21%).

[10] The grave boxes in Sector G were the sole exception; their assignment to the Middle Necropolis was due most likely to methodological differences.

[11] Actually, the results of the investigations in Sector G reflected the stratigraphic reality of the burial ground in a much better way than any earlier or later archaeological explorations on the site.

Table 3. Frequency of given age groups in the age-at-death evaluation of individuals buried in the cemetery, broken down by three chronological phases.
Fractional number of individuals (*n*) in particular groups is due to individuals with age-at-death range covering more than one age-at-death bracket

	0–7		7–14		14–20	
	n	%	*n*	%	*n*	%
Lower Necropolis	57.37	19.58	23.07	7.88	30.07	10.26
Middle Necropolis	20.97	12.19	5.71	3.32	5.63	3.27
Upper Necropolis	381.84	18.11	95.06	4.51	181.16	8.59
?	2.00	9.52	0.46	2.20	1.54	7.33
Σ	462.18	17.81	124.30	4.79	218.40	8.42

	20–35		35–55		55–x		Σ	
	n	%	*n*	%	*n*	%	*n*	%
Lower Necropolis	67.07	22.89	75.50	25.77	39.92	13.62	293.0	100.0
Middle Necropolis	25.01	14.54	84.19	48.95	30.48	17.72	172.0	100.0
Upper Necropolis	493.43	23.40	588.43	27.90	369.09	17.50	2109.0	100.0
?	8.56	40.75	8.06	38.37	0.39	1.84	21.0	100.0
Σ	594.07	22.89	756.18	29.14	439.87	16.95	2595.0	100.0

Table 4. Frequency of given age groups in the age-at-death evaluation of adult individuals buried in the cemetery, broken down by three chronological phases, taking sex into consideration.
Fractional number of individuals (*n*) in particular groups is due to individuals with age-at-death range covering more than one age-at-death bracket

	Sex	20–35		35–55		55–x		Σ	
		n	%	*n*	%	*n*	%	*n*	%
Lower Necropolis	♀	26.48	42.21	26.05	41.53	10.20	16.26	62.73	100.0
	♂	26.09	29.99	36.17	41.58	24.74	28.44	87.00	100.0
	?	14.51	44.29	13.27	40.52	4.97	15.18	32.75	100.0
	Σ	67.07	36.75	75.50	41.37	39.92	21.87	182.49	100.0
Middle Necropolis	♀	10.59	19.05	36.13	65.01	8.86	15.94	55.58	100.0
	♂	11.48	16.63	40.54	58.75	16.99	24.62	69.01	100.0
	?	2.95	19.52	7.53	49.83	4.63	30.65	15.11	100.0
	Σ	25.01	17.91	84.19	60.27	30.48	21.82	139.68	100.0
Upper Necropolis	♀	271.95	40.96	245.35	36.95	146.67	22.09	663.97	100.0
	♂	200.61	27.93	314.80	43.83	202.90	28.25	718.31	100.0
	?	20.87	30.40	28.28	41.18	19.51	28.42	68.66	100.0
	Σ	493.43	34.01	588.43	40.55	369.09	25.44	1450.95	100.0
Σ	♀	2.00	100.00	0.00	0.00	0.00	0.00	2.00	100.0
	♂	1.50	30.00	3.50	70.00	0.00	0.00	5.00	100.0
	?	5.06	50.57	4.56	45.57	0.39	3.86	10.01	100.0
	Σ	8.56	50.34	8.06	47.39	0.39	2.27	17.01	100.0

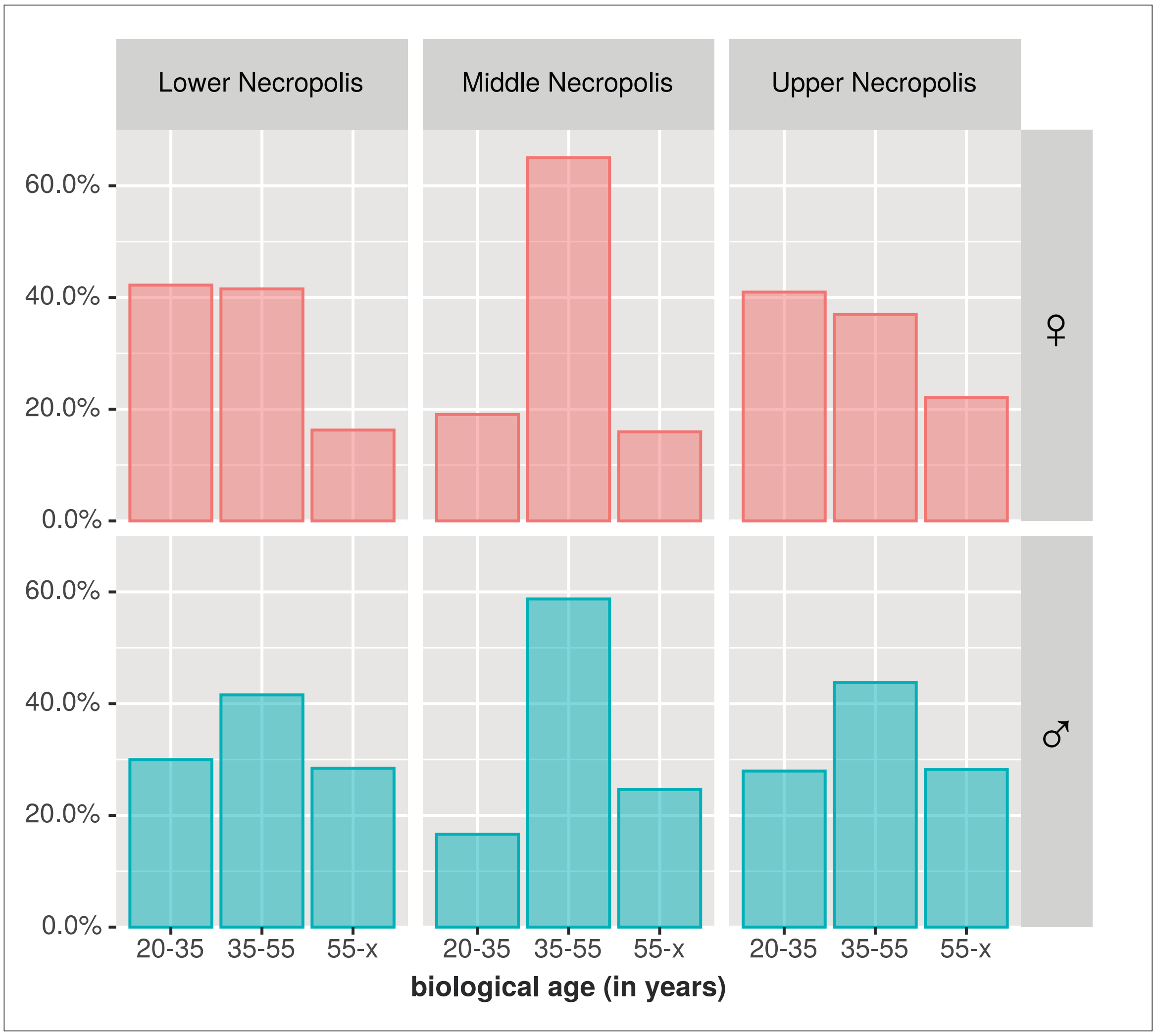

Fig. 18. Percentage share of given age groups in the age-at-death evaluation of adult individuals buried in the cemetery, broken down by three chronological phases, taking sex into consideration

Preliminary bioarchaeological analysis encompassed not only age-at-death frequencies. The sex ratio analysis revealed no anomaly that could be interpreted in the context of the validity of the three phase division of the cemetery. And to consider the problem from the point of view of the stature of the deceased proved unfeasible, this because of the almost complete lack of any bone-length data for the Middle Necropolis due to the poor state of preservation of the skeletons from the group. Further work concerning human remains was conducted using the reinterpreted chronological division of the cemetery (see *Chapter 3*).

2.4 Chronological framework

Establishing the chronological frame for the Islamic cemetery on Kom el-Dikka is constrained by the absence of typical archaeological dating markers—no coins to conveniently set the beginning on the one hand and pottery evidence that is too common and fragmented to be of any but general chronological value on the other. One is left with circumstantial dating evidence, still and at least for now.

When the cemetery was first discovered, it was conjectured on fairly general grounds that the burials were from the 13th century, the times of the Crusades and of frequent earthquakes (Dąbrowski 1966: 178). The 12th-to-15th century timeframe was defined by the ceramics and glass artifacts from the trial trenches excavated on the spot (Dąbrowski 1960: 47). The growing body of data on site stratification, accumulated with the progress of excavations, quickly led to a revision of these early estimates. In her comprehensive study of the age-at-death of this population published in 1972, using the three-phase periodization, Promińska followed Kubiak (1967a: 52) in dating the beginnings of the initial phase of the cemetery, the so-called Lower Necropolis, to the end of the 7th and the 8th century (Promińska 1972: 13). Her view continues to be entrenched in Kom el-Dikka studies. The first burials on Kom el-Dikka are currently linked to the beginning of Arab rule in Alexandria (Majcherek 2007a: 22; Majcherek and Kucharczyk 2014: 25).

This early dating, at least with regard to the archaeological site here discussed, cannot be upheld once the evidence is reviewed and especially when the time between the abandonment of the late antique buildings on the site and the first inhumations is factored in, both within the ancient walls and immediately outside.

At the other end, the latest use of the Islamic cemetery was initially placed rather vaguely between the 16th century and the year 1798 when the French commenced preparations for building a fort by piling a high mound of earth (Dąbrowski 1966: 176). This changed with the advance of the fieldwork and was generally moved back in time. Promińska (1972: 13) put the border date in the 14th century, although one wonders why she did not consider Kubiak's well reasoned proposition to date the end of burial activities on the site to the 12th century (Kubiak 1967a: 50–51). His dating continues to be valid even today (Majcherek 2007a: 22).

2.4.1 Beginnings

The sole border date that had existed until now—the earthquake of 796—has lost its distinctness now that it cannot be considered as a *terminus ante quem* for the last burials in the Lower Necropolis (for the discussion see above, *§ 2.3.2*). In addition, the replacement of the three-phase division with a two-phase one, combining the first two phases into one throughout the site (argued above, *§ 2.3*), suggested an entirely new interpretation. Without this date to constrain thinking, one now has greater freedom to marshal the information on the beginnings of the cemetery from other sources and assess its relevance and reliability.

As described above, the situation of the inhabitants of Alexandria immediately after the conquest by the Arabs was not as evident as that of the people in the provinces. Even there, immediate Arabization and all the more so, an unproblematic Islamization of the population were not imminent. A new poll tax introduced by the Arabs concerned the Christian and Jewish inhabitants, and it must have hit hard all those who under the Romans had been exempt from taxes for whatever reason (Butler 1902: 453–454). Many citizens of substance chose to leave the city right after the conquest. The void left by departing Byzantine officials and the privileged Melkites was filled by the previously marginalized Monophysite elite (Butler 1902: 450), although the process was most probably not as rapid as previously assumed (Mikhail 2014: 27, 39–40). The collapse of Alexandria's lucrative trade was compensated for only in part by the frequent raids on Byzantine coastal towns in the early years after the Arab conquest (Foss 2009: 273). Excessive taxation resulted in successive Coptic rebellions in Egypt starting from 725–726 (Kennedy 1998: 65, 67), which could not but have had a negative impact on the economic situation of the inhabitants.

Alexandria was unlike the rest of the country in that it had a large garrison of 12,000 men stationed there almost from the beginning of Arab rule, a number that was soon doubled (Foss 2009: 272). For a long time, it was the only place outside of Fustat and Aswan (where a garrison was stationed soon after the conquest, Gascoigne 2002: 3) with a substantial Arab population in residence (Kennedy 1981: 32). Progressing Arabization, like Islamization, was not a violent process and in Alexandria, where Byzantine officials were replaced first by Melkites and then by Copts (Mikhail 2014: 27, 39–40), Arabization must have proceeded even more slowly than elsewhere. Otherwise it appears to have enjoyed exceptional status among the cities of Egypt, Fustat excluded, largely preserving its character from before the conquest and sustaining it for a long time afterwards. It seems probable, especially taking into account the central role of Fustat in the life of Muslims in Egypt and their unwillingness to settle elsewhere, as well as the degree of Islamization which was not launched for good as a process until the mid-8th century.

About a hundred years of prosperity after the Arab conquest (Kubiak 1998: 18) ensured a fair amount of independence[12] and everyday life in the city could have remained basically unchanged until the 9th century (Haas 1997: 343). In light of this one should assume that the central districts of Alexandria, including the monumental late antique academy and huge square extending west of it, most probably lost importance (Kołątaj 1976: 219) after the conquest, but may have continued to be a working part of the city. Earthquakes, rebellions and ten years of a recent Persian occupation had already weakened the urban fabric of Alexandria (Fraser 1993: 97; Fraser 1991: 88; Kaegi 1998: 43) even before the coming of the Arabs. Large areas of the town were being used as rubbish dumps from the mid-5th century; earth, rubble and ceramic waste accumulated, forming huge artificial mounds (Fraser 1993: 94; Rodziewicz 1998: 379–380; Tkaczow 2000: 138). Archaeological investigations in different parts of the city have demonstrated the continuity of these processes from the late antique to the early Islamic periods (Gascoigne 2002: 1). But memories of the fabled Alexandria with its monumental buildings, its theater and its lecture halls, continued to fire the public imagination long into Arab times (McKenzie 2007: 79–83). The ancient street grid survived the longest, into the late medieval period (Haas 1997: 340; Rodziewicz 1998: 370, 376), and its vestiges are still to be seen today.

The site of the later burial ground was situated in the very center of the ancient city (McKenzie 2007: 53, 72). It is difficult to say when this area was ultimately abandoned, but it was not, in all likelihood, before the mid-7th century, that is, already after the conquest, both for the lecture halls (Majcherek 2007a: 28) and the bath complex (Kołątaj 1976: 219). Therefore, the beginnings of the Islamic cemetery on Kom el-Dikka should be placed with a fair amount of certainty not earlier than the 8th century and perhaps even in the second half of the 8th century in the case of the area of the late antique academy complex.

[12] The reverse is also possible, meaning that Alexandria's relative independence even after the conquest allowed it to enjoy a hundred years more of prosperity.

The earliest dated monument from the Kom el-Dikka cemetery is a stela bearing the date 247 AH (861 CE) [*Table 5*: No. 7]. It was found reused in the structure of a tomb from the late phase of the cemetery (Kulicka 2007: 38–39; Majcherek 2007a: 22) and was probably salvaged from its immediate neighborhood, presumably in the course of its digging, possibly even from a superstructure located directly under this grave (Lower Necropolis superstructures and Upper Necropolis grave box foundations were more or less on the same level). An earlier Arabic stela, dated to about 190 AH (805 CE) is said to be from Kom el-Dikka, but its exact provenance is not known (Combe 1936: 56–58). Another epitaph, on a stela found next to the Nabi Daniel Mosque located about 51 m southwest of the archaeological site, was dated to around 200 AH (815 CE) (Combe 1936: 58) [*Table 5*: item 1]. Neither date is precise, being based on a paleographic assessment of the writing. The earliest stela with a given date and known provenance was found in the same general area (Combe 1936: 61–62), near the Nabi Daniel Mosque. It commemorated a man who died in 220 AH (835) [*Table 5*: item 4]. The relatively insignificant distance from the trenches on Kom el-Dikka and a close similarity to other finds of the kind from the burial ground lead to the assumption that the stela was part of the same early cemetery that is now identified on Kom el-Dikka as the Lower Necropolis (Dąbrowski 1966: 172, 178).

The set of dated stelae from the Kom el-Dikka cemetery includes 21 inscriptions from the 9th century, seven from the 10th century, nine dated more broadly to the 9th–10th century, only one from the 11th century and 10 from the 12th century [*Table 5*]. Should they be considered as the sole premise upon which to base the dating of the first phase of burials on Kom el-Dikka, the date indicated would be the first half of the 9th century. The complete absence of any stelae that could be assigned to the 8th century, in the face of the evidence for this form of commemoration being known and used in Egypt at the time, notably the stela from Aswan (Redlak 2011: 561), is a strong indication for a later dating of the beginnings of the necropolis on Kom el-Dikka. A more orthodox attitude to burial or the costliness of putting up such markers, especially for the poorer classes of the urban population, could be cited as reasons for the absence of stelae in the earliest years (Halevi 2007: 16; Simpson 1995: 247). However, this scenario does not seem likely in face of the number of excavated graves and the size of the explored area, as well as the number of actually dated epitaphs, which reaches 48.

Earlier, a *terminus ante quem* for the beginnings of the cemetery, on a par with the earthquake of 796, was supplied by an inscription in Arabic placed on the side of a marble pedestal found standing in the Theater Building. This text consists of two formulas referred to as funerary, virtually identical in content, but carved most probably by two different hands, although this particular observation is not mentioned in the original publication (Kubiak 1975: 134). The paleographic dating of this inscription, or rather two inscriptions, places them in the end of the 7th–early 8th century, thus supplying a date for the earliest use of the area for burial purposes. In both instances, the formula had the same invocation: "Let God have mercy on", and the name of the commemorated individual. The laconic character of these texts when compared to the content of the inscribed funerary stelae found in the cemetery, questions the strictly funerary function of these two texts. In the opinion of arabist Dorota Malarczyk (personal communication, 2016), the formula "…Rahmat Allah …" may be used just as well for a living person reading the inscription and should not be linked solely with a funerary context.

Table 5. Dated Arabic funerary steles from Kom el-Dikka with established provenance (not included: texts without a preserved date formula, recorded provenance or paleographic dating). 'In pub. no.' – information derived from publication, 'AH' – year in the Islamic calendar as read on the stele, 'CE' – date in the Gregorian calendar calculated based on the Islamic year; 'Analysis (publication)' – name of researcher and year of publication (if published)

No.	In pub. no.	Inv. no.	Paleographic dating	AH	CE	Analysis (publication)
1	2	23888	815	–	–	E. Combe (1936)
2	3	23887	830	–	–	E. Combe (1936)
3	5	23884	835	–	–	E. Combe (1936)
4	6	23889	–	220	835	E. Combe (1936)
5	7	23885	860	–	–	E. Combe (1936)
6	8	23890	–	246	860	E. Combe (1936)
7	–	5111	–	247	861	D. Malarczyk
8	–	1088	–	256	870	D. Malarczyk
9	–	5122	–	256	870	D. Malarczyk
10	–	3593	–	280	893	D. Malarczyk
11	1	SG 636	first half 9th century	–	–	W.K. Kubiak (1975)
12	2	SC 628	first half 9th century	–	–	W.K. Kubiak (1975)
13	3	SD 593	first half 9th century	–	–	W.K. Kubiak (1975)
14	2	SM 946	first half 9th century	–	–	W.K. Kubiak (1975)
15	13	SM 949	mid-9th century	–	–	W.K. Kubiak (1975)
16	4	SA 13	second half 9th century	–	–	W.K. Kubiak (1975)
17	5	SD 597	end 9th century	–	–	W.K. Kubiak (1975)
18	6	SL 665	9th century	–	–	W.K. Kubiak (1975)
19	7	SL 667	9th century	–	–	W.K. Kubiak (1975)
20	4	SK 695	9th century	–	–	W.K. Kubiak (1975)
21	6	SM 850	9th century	–	–	W.K. Kubiak (1975)
22	11	SD 592	9th–10th century	–	–	W.K. Kubiak (1975)
23	12	SC 616	9th–10th century	–	–	W.K. Kubiak (1975)
24	13	SC 631	9th–10th century	–	–	W.K. Kubiak (1975)
25	7	SM 907	9th–10th century	–	–	W.K. Kubiak (1975)
26	8	SM 823	9th–10th century	–	–	W.K. Kubiak (1975)
27	9	SK 736	9th–10th century	–	–	W.K. Kubiak (1975)
28	10	SM 699	9th–10th century	–	–	W.K. Kubiak (1975)
29	11	SM 839	9th–10th century	–	–	W.K. Kubiak (1975)
30	12	SAN 896	9th–10th century	–	–	W.K. Kubiak (1975)
31	8	Muz. Gr-R. 442	–	289	902	W.K. Kubiak (1975)
32	–	5070	–	300	912	D. Malarczyk
33	5	SM 951	first half 10th century	–	–	W.K. Kubiak (1975)
34	9	SC 613	10th century	–	–	W.K. Kubiak (1975)
35	10	SC 559	10th century	–	–	W.K. Kubiak (1975)
36	–	SM 950	10th century	–	–	Kowalska (1970)
37	–	SC 967	10th century	–	–	Kowalska (1970)
38	3	SM 945	second half 10th century	–	–	W.K. Kubiak (1975)
39	–	1697	–	502	1108	D. Malarczyk
40	–	5063	–	505	1111	D. Malarczyk
41	14	SC 608	–	518	1124	W.B. Kubiak (1967)
42	17	SM 993	–	574	1179	W.B. Kubiak (1975)
43	–	1077	first half 12th century	–	–	M. Kowalska (1970)
44	–	1086	first half 12th century	–	–	M. Kowalska (1970)
45	19	947	second half 12th century	–	–	W.B. Kubiak (1975)
46	16	SM 925	12th century	–	–	W.B. Kubiak (1975)
47	18	SM 952	12th century	–	–	W.B. Kubiak (1975)
48	20	SK 694	12th century	–	–	W.B. Kubiak (1975)

Even the earliest stelae known from other regions of Egypt were much richer in content. One of the oldest inscriptions of this kind, presumably Islamic, comes from the so-called Fatimid cemetery in Aswan and is dated to 31 AH (652 CE) (Redlak 2011: 561). Thus, another form of commemorating the burial was already in place when the burial ground on Kom el-Dikka emerged. Hence, it is not the early date of these two texts, but rather a different purpose, that justifies their relative simplicity and their localization on the pedestal in the theater. Moreover, the absence of a reference to the Prophet, which is also a characteristic feature of the Aswan stela (Halevi 2007: 15), suggests that these two texts are a testimony to the arabization or even just Arab presence at this place and time, rather than a progressing Islamization of the population as such.

The stratigraphy of the site does not add much to the picture drawn by the epigraphy. For dating the beginnings of the cemetery. It is circumstantial evidence at best. Since the Lower Necropolis tombs were often cut into ancient structures in rather accidental manner (Kołątaj 1976: 219–220; Kulicka 2007: 38), one has to assume that awareness of the location of these ruins was somewhat vague [*Fig. 19*]. Burials were most probably not careless or hurried as Dąbrowski originally assumed (1966: 178). It means that there was already a fairly thick accumulation of later deposits concealing the late antique layers, except for the best preserved structures. The time needed for this accumulation to form is difficult to estimate, but one can safely assume that it did not occur overnight.

In the so-called Theater Portico, the superstructures of the Lower Necropolis[13] were found about a meter above the ancient pavement (Kulicka 2010: 53). Other superstructures from this phase were discovered on approximately the same level in the Southern Portico of the Roman Bath (Kołątaj 1976: 223). According to Majcherek (personal communication), deposits approximately 15 cm thick accumulated on the site over ten years in the 1990s. Even assuming a large margin of error, the time needed for this meter of earth to accumulate was at least half a century, but no more than a century.

Inside the lecture halls, which had lost the roofs but still had all the walls standing high, the rate at which the chambers were filled with deteriorating architectural rubble, as well as sand and earth brought in by the wind, would have been more rapid than in the open spaces of the portico that lined an empty square, giving a meter of deposits in a much shorter time (Majcherek 2007a: 22).

Fig. 19. Child grave cut into the bench of lecture hall G; grave box G-305 marked with a circle

[13] Readers accustomed to the three-stage phasing of the cemetery should remember that when superstructures of the Lower Necropolis are mentioned, they were previously interpreted as belonging to the Middle Necropolis phase.

Nonetheless, without any tomb superstructures located inside the halls, it is impossible to determine the walking level from which the digging of the graves would have commenced. Since the substructures were found at the same level as elsewhere in the neighborhood and there were no superstructures approximately one meter above the floor, it is possible that, by analogy with their experience of excavating grave pits in the portico, the gravediggers knew that they had to dig deeper until they had cut into the pavement. The other possible scenario is that the interiors of the chambers were cleared of drifted deposits as long as they were in use, while no one bothered about the rising ground level in the portico, and in consequence, the level inside the lecture halls (including erosion of the walls etc.) may have matched that in the portico at the time of the first burials there.

To sum up, the first epigraphic proof of tombs in the area of the Kom el-Dikka cemetery is from the 9th century, whereas circumstantial evidence mainly from an analysis of the stratigraphy within the excavated area suggests that the first burials were made not earlier than in the 8th century, perhaps even not earlier than the second half of the 8th century, depending on the rate at which new layers were formed and the precise moment in time when the area went out of use. Therefore, the earliest paleographic dates provided by stelae, pointing to the beginning of the 9th century, may be considered as the most likely for the initial phase of the cemetery.

2.4.2 Between phases

There is no precise date for when the early phase of the cemetery (now Lower Necropolis, combined former Lower and Middle Necropolises as argued in *§ 2.3*) went out of use, even though from an archaeological point of view the differences between the structures of the two phases are obvious in most cases. A reasonable assumption has to be made just as in the case of its beginning.

Financial issues were at the root of the failure of the Abbasid administration, which replaced the Umayyad one in the middle of the 8th century, to cooperate effectively with local authorities. Rebellion followed tax hikes and a non-local candidate governor filling the office in the last quarter of the 8th century. The revolt was bloodily suppressed, but stability was not restored and the next years were marked by frequent insurgencies, general unrest and regular changes of the caliph's official in charge of the province (Kennedy 1998: 76–82). Isolation of the once proud metropolis deepened following a decade of rule by Andalusian outcasts who took it by force in 814 (Gascoigne 2002: 15) and its role in Egypt diminished considerably. Extensive changes came with the establishment of the Turks in Egypt in 827. From 829, the province governor was nominated by the administrator of the western provinces in lieu of the caliph, and a few years later the last remnants of the order introduced after the conquest disappeared when all were dropped from the *diwan* list and the payments to them ceased (Kennedy 1998: 82, 84).

Order was restored by Ahmad Ibn Tulun, who started out as a governor of Egypt in 868 before establishing effectively his independence from the Caliph. Ibn-Tulun cured the finances and strengthened the infrastructure. Under constant threat from the Abbasids, he restored the city walls of Alexandria (Bianquis 1998: 98–99; Isma'il 1993: 155). The two new circuits constructed in 858 and 866 (Kubiak 1998: 18–19), encircling only about a quarter of the area of ancient Alexandria, attest to a much smaller population, estimated at only about 60,000–70,000 (see *Chapter 1*). The new fortifications and the reconstruction of the underground aqueduct in the second half of the 9th century, commissioned as a matter of fact by the Christian administrators

(Kubiak 1998: 18), are proof of the vitality and relative independence of the city, but it was hardly enough to keep people from leaving. The new centers of power, the city of al-Askar founded north of Fustat by the Abbasids at the very beginning of their rule, as well as al-Katta'i called into existence by Ibn Tulun in 868 (Raymond 2005: 33–35), attracted migrants from Egypt's main urban centers (Gascoigne 2002: 15–16). These new cities were certainly not as promising locations as Fustat, even after the fire that destroyed the latter in 750, but their emergence could have redirected the funds available for new investments. The migrant wave that presumably left Alexandria, heading for these new centers, never returned.

The beginning of the 10th century, after the return to power of the Abbasids in 905, was again a time of unrest. Three times between 914 and 936 Alexandria fell to Fatimid invaders, and while the occupants retreated each time (Bianquis 1998: 111–112), the position of Alexandria and its population must have been severely weakened. The second part of the century was a time of relative peace, which may have helped in the revival of the city. In the end of the 9th and in the first 60 years of the 10th century, Alexandria had to deal also with the effects of repeated destructive earthquakes in 885, 912, 936, 951 and 956 [see *Table 6*], the last one apparently sealing the pre-Fatimid days of the city. The cemetery on Kom el-Dikka is likely to have revived after this event, at a time corresponding more or less to the economic and political stabilization that followed the advent of Fatimid rule in 968 (Sanders 1998: 158, 161).

The epigraphy is not conclusive in defining the end of the Lower and the beginnings of the Upper Necropolis phase. All the stelae found *in situ* in the context of the Lower Necropolis superstructures are dated to the 9th–10th century, whereas those marking graves of the Upper Necropolis phase, even when dated only on paleographic grounds, do not extend beyond the frame set by the 11th and 12th centuries [*Table 5*].

An almost direct vertical continuity between the two phases, Lower and Upper, can be observed in the area west of the late antique academy complex (Sector E on the border with CV, in the portico and west of it, in Sector CV in the portico alone and in Sector U to the northeast; see Kulicka 2015: 67), but in other parts the difference in foundation level was very well marked (vertical differences from half a meter to a meter and a half in Sector E, the eastern part of Sector G, the eastern end of Sector CV, sectors AS and A; see, e.g., Dąbrowski 1966: 175, 178) [see *Figs 8, 9*].[14] Inside the area once containing antique residential buildings, a substantial refuse layer had first to form over the superstructures of the Lower Necropolis before the graves of the Upper phase could be built. It was due presumably to the ever growing rubbish dump located in the center of the site and accumulating there, with interruptions, since late antiquity. The Theatre Portico was a natural boundary for this rubbish dump on the western side.

The uneven gap between the two general phases reflects the time that must have passed since the probable abandonment of the Lower Necropolis in the middle of the 10th century and the first graves of the Upper Necropolis that most probably appeared there no sooner than in the first half of the 11th century, more likely even later as attested by the only stela dated to the second half of this century.

[14] The anomaly from loci U and W in sector CW, where superstructures assigned to the Lower Necropolis are found below the tops of grave boxes from the same phase, should be disregarded most probably as the outcome of an error in reading and calculating elevations on one of the excavation plans.

2.4.3 The end

Again, the strongest dating evidence demarcating the end of the necropolis on Kom el-Dikka, like that for its beginning, comes from the inscribed funerary stelae. Ten monuments from the 12th century (with just one from the 11th century) support a late date for the first graves belonging to the Upper Necropolis in the area and they also indicate that the graveyard ceased to be used most probably in the end of the 12th century. The latest exact date given in an epitaph is 574 AH (AD 1179). It corresponds well with the end of Fatimid rule in Egypt, the incursion of the Crusaders under Amalrik I in 1168, the siege of Cairo by Syrian forces a year later, and the taking of Egypt in 1175 by Salah al-Din Ibn Ajjub (Saladin), and the establishment of his dynasty, the Ayyubids, within two years of that event (Raymond 2005: 76–80, 84).

As mentioned already, the Fatimids brought stabilization and prosperity back to Egypt. Alexandria clearly benefited from the new arrangements, although at the same time its autonomy was seriously limited. Revived sea trade in the Eastern Mediterranean as well as with the West, that is, Andalusia and Maghreb, and an extremely lucrative trade by land routes with Aghlabid Ifrikija started already at the turn of the 9th century (Bianquis 1998: 87). Back then, Alexandria was still in a period of unrest and inner conflicts, but by the end of the 10th century, with the beginning of Fatimid rule in Egypt, it had recovered again and flourished (Kubiak 1967a: 69), much like the other Mediterranean harbors of Egypt, Tinnis and Damietta (Bianquis 1998: 88). Interestingly, this presumed positive trend in prosperity, which would be coincident with Egypt's economic success in this period (Sanders 1998: 161–163), was not directly reflected in ceramic imports. The marginal presence of imported pottery in assemblages consisting mostly of vessels of local Egyptian production, excavated from layers associated with the earliest phase of the burial ground on Kom el-Dikka, is believable in the light of the historical context discussed above. However, the almost complete absence of imports among the mostly Egyptian pottery (Kubiak 1969: 9–10) with regard to the Upper Necropolis calls for an explanation. Kubiak argued convincingly that the mastery of ceramic production reached by Egyptian potters was such that it made all imports of ceramics practically unnecessary. Indeed, in this period, according to Kubiak, Alexandria took on the role of the main shipping center for exported Egyptian ceramics and glass (Kubiak 1969: 23). However, after a century of peace and prosperity, the Fatimid economy took a blow with the loss of Syria in 1076, succumbing to a growing pressure from the Crusaders, who conquered Palestine in 1098–1099, and the years of hunger and unrest caused by failing harvests in the times of the Caliph Al-Mustansir. While trade did not collapse in its entirety (Sanders 1998: 162), the income from commerce was much depleted. The famine decimated the population of Fustat and Cairo (Sanders 1998: 152–153), and the concurrent mass exodus of the craftsmen from Fustat led to a gradual decline and disappearance of the local luxury ceramic wares (Kubiak 1969: 24–25).

These drastic changes taking place in the second century of Fatimid rule in Egypt were apparently not reflected in the composition of the pottery assemblage from the rubbish layers associated with the Upper Necropolis (Kubiak 1969: 10). A possible explanation is that the area may have stopped being a convenient dumping ground and this would have been because of the expanding cemetery, which could have started already to move up the slopes of the mound covering the late antique architecture to the east (the center of the medieval cemetery was located presumably in the square extending west of the Theater Portico, see below, *§ 2.6*).

The chronological horizon provided by funerary stelae, marking the end of the Upper Necropolis on the site, fully agrees with the pottery evidence. According to Kubiak (1967a: 49), the pottery from the layers that accumulated over the latest graves in Sector G can be dated to the 13th–14th century. So also Jadwiga Lipińska regarding the funerary structures in Sector H, which she dated to directly before the coming of the Mamluks (Lipińska and Riad 1966: 101), and Rodziewicz (1982: 40), who indicated the 13th century as the time when layers of rubble covered the last vestiges of the Upper Necropolis. Kołątaj agreed with the dating and observed that the Mamluk coin hoard from Sector Q testifies to the abandonment of the cemetery by this time, even though, at least in this part, it had not yet been covered by the 13th- and 14th-century rubbish (Kołątaj 1976: 227). Finally, the form of the *mihrab* that was modeled in the plaster of the tomb superstructures, common in the architecture of the period (Kubiak 1967a: 69), also points to a Fatimid date for the Upper Necropolis [see below, *Fig. 22*].

The long functioning of the second and last phase of the cemetery is borne out also by the number of burials occurring in a single grave (Kubiak 1967a: 51), reaching in several instances a dozen or so individuals, and no less than 30 human skeletons in the most numerous set (see the Catalog of burials B.1 in Appendix B, item o1968-24/68). Sporadic burials may have taken place in the cemetery also at the beginning of the 13th century and even later, but there is no way to distinguish these late inhumations, especially if they were added to existing tombs.

2.5 Grave typology

In view of the fact that the reasoning against distinguishing a Middle phase of the necropolis turned on the general form of the grave, the established typology of grave structures at Kom el-Dikka deserves separate attention. It made sense, however, to wait with the discussion of the grave typology to after arguing the revised phasing of the cemetery simply in order to avoid unnecessary confusion.

The graves from the cemetery share the same general characteristics and look basically the same, especially the simple earth burials, regardless of the phase. However, the numerous stone (and brick) tomb structures, both substructures (grave boxes) and superstructures (including tombstones), make all the difference.

2.5.1 Lower Necropolis

A typical grave box from the Lower Necropolis was a single-inhumation structure built of relatively large, roughly dressed stone blocks. The average dimensions of these blocks are approximately 0.22 m × 0.40 m × 0.38 m. They were set up on end, in one line, forming a rectangular enclosure, which acted as an enclosure for the corpse. Rectangular slabs of limestone, averaging 0.60 m × 0.35 m × 0.10 m in size, were laid flat on top to cover the box [*Fig. 20*]. The walls of these grave boxes, cutting into the late antique ruins, were sometimes adapted from what stood in the ground, but the overall form was retained. Earth burials were also practiced, furnished with a covering of horizontal slabs that is characteristic of the phase (Dąbrowski 1966: 176; Kulicka 2011: 483–485); in Sector CV, pit graves were discovered with the covering limestone slabs sloped in one direction, descending to the northwest (Kulicka 2016: 54), that is, behind the back of the deceased.

Fig. 20. Typical grave box (CW-330) of the Lower Necropolis

Direct parallels for the Lower Necropolis grave substructures, although for the most part much later in time, from the Mamluk and Ottoman periods, can be found in the territories of nearby Israel/Palestine (Gorzalczany 2007: Fig. 3; 2016: 71–72, 101; Yoav 2017: 94, 96).

Typical superstructures from this phase (formerly identified as the Middle Necropolis) consist of a rectangular frame of stone blocks set directly on the ground and plastered, including the space inside the frame to form a kind of floor. The limestone blocks used for this purpose were relatively large (about 0.25 m × 0.25 m × 0.30 m) and regularly dressed. They surrounded an area that was frequently much larger than would be expected for a single grave, large enough sometimes for two (and more) grave boxes inside the outline [see *Fig. 10*]. An inscribed stela would be placed in a hollow made in the frame on either the eastern or the western side of the superstructure, the inscription facing either east or west [see *Figs 11*; *12*]. In some parts of the cemetery, a bed of sea sand with an abundance of crushed shells and small pebbles would appear on the walking level around the superstructure (Kulicka 2011: 485–488).

Emanuela Kulicka quoted parallels from Aswan (Kulicka 2011: 488) but without giving any details to help identify the similarities. The typology of tombs from the Southern Cemetery of the so-called Fatimid Cemetery in Aswan (Björnesjö and Speiser 2015: Fig. 5) does not reveal any direct parallels for the shape of the superstructure, unless one assumes as such the rectangular frame of the superstructure of Type I from Aswan with the simple grave pit underneath. The Kom el-Dikka burial ground is actually full of simple pit graves, but any direct link with superstructures is equally difficult to prove as in the case of the link between grave boxes and superstructures of the Lower Necropolis. Earth burials are found also on the grave boxes and between them, which indicates that they were dug into existing structures. In addition, a rectangular frame is not enough for a viable parallel, especially if one takes into account the rough dressing of the stones in the Aswan cemetery and the rather blunt edges of outlines, which create an oblong rather than rectangular shape. Nor was there any evidence of plastering on the superstructures of Type I in Aswan.

2.5.2 Upper Necropolis

The Upper Necropolis featured a much greater variety of types of substructures and superstructures. These were better built features and the stone blocks used in their construction were visibly smaller in size compared to the building material of the earlier phase. The grave boxes were much larger in comparison, designed to hold multiple burials, which was the practice in the later phase. A dozen or so burials in a single tomb was nothing unusual there. The bones of earlier inhumations were pushed to one side of the box, usually to the west. The corpses were introduced most probably through a hole in the roofing,[15] which was made when needed by removing the slabs from the eastern end. Frequent evidence of damage to this end of the tomb structure seem to confirm this practice. The reverse was possible but not common. In Sector CW, only 10% of the tombs had the bone remains pushed to the eastern end of the tomb (Kulicka 2011: 493; Kulicka 2010: 54). Human bones that were disturbed when digging a tomb, for example, could have also been placed there (Kubiak 1967a: 50). In a few rare instances, the corpses could have been laid one on top of the other (Kulicka 2011: 493), possibly with an intervening, thin layer of earth covering the earlier inhumations.

The simplest grave boxes of the Upper Necropolis were very similar to the substructures known from the Lower Necropolis [*Fig. 21*: type A]. The construction was basically the same, but the blocks used for walls were not that big, measuring 0.40 m × 0.20 m × 0.15 m on average (Kulicka 2011: 483–484, 489), therefore giving the impression of better quality. Other forms typical of this later phase were constructed of smaller stone blocks, averaging 0.14 m × 0.20 m × 0.15 m (Dąbrowski 1966: 173), sometimes using bricks as well (Kulicka 2011: 491). These were rectangular cists with high walls and an earth floor, and a slab ceiling that was either flat [*Fig. 21*: type B] or gabled [*Fig. 21*: type C]. The new gabled covering allowed boxes of a larger width to be constructed, or else the slabs used for the covering could be smaller, meaning more easily supplied. The type with gabled roof [*Fig. 22* at the top] had two more elaborate variants. The first had the walls of the box rising to the ground surface along the whole perimeter [*Fig. 22* in the middle]. The second also had the walls raised to the ground level but only in a part of the perimeter, most often at the eastern end, thus forming a shaft [*Fig. 22* bottom]. In both cases, the advantages are evident: successive burials could have been made without digging.

The superstructures of the Upper Necropolis can be classified in three general groups. The oldest tomb markers were formed probably as a rectangular frame made of large, well dressed vertical limestone slabs [*Fig. 21*: type 1] fitted together, joined, either using a wedge put into slots made in the adjoining sides or bonded in mortar (Kulicka 2015: Fig. 9; Kulicka 2011: 491). Newer structures, repeating an earlier feature in the same spot, were common; they were built of

[15] In shaft tombs, successive burials were made through a hole in the roofing covering the shaft [*Fig. 22* bottom].

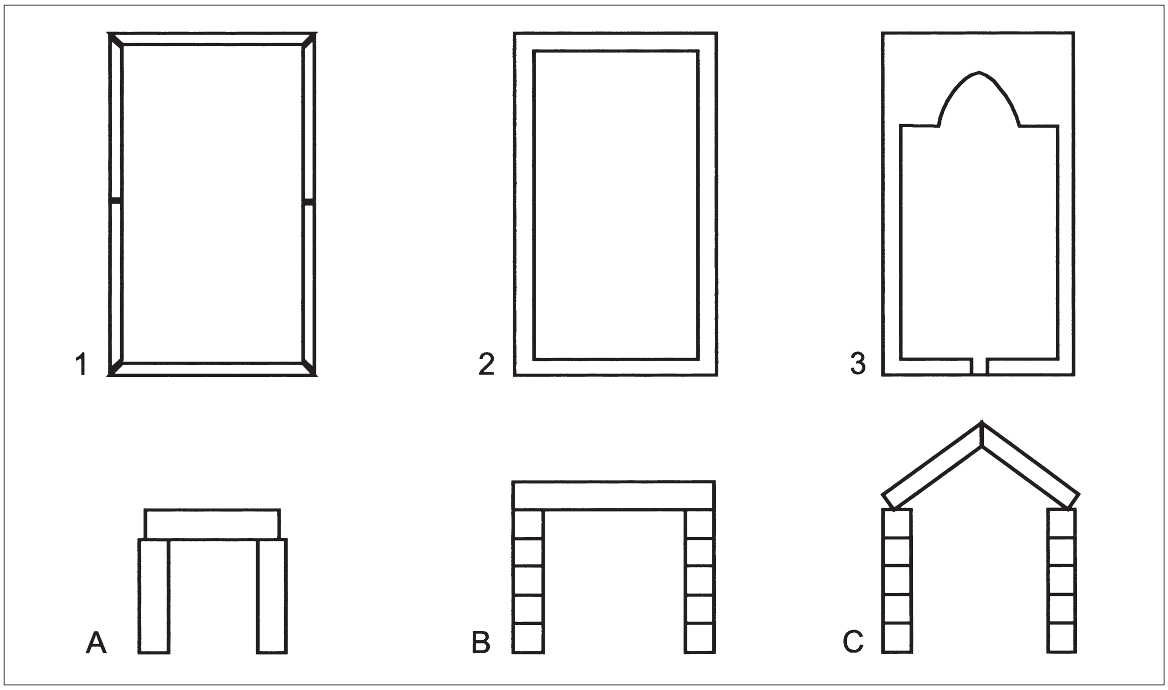

Fig. 21. Types of superstructures (1–3), view from above, and grave boxes (A–C), north–south section, Upper Necropolis

small well-dressed limestone blocks and baked bricks. They were rectangular in outline, sometimes stepped, forming a frame around a hollow, which could be rectangular [*Fig. 21*: type 2] or in the shape of a flat *mihrab* [*Fig. 21*: type 3], situated at the western end of a tomb (Kulicka 2011: 491–492). The superstructures made of vertical slabs, which have been considered as earlier, could be a poorer rather than older version replaced some time after the funeral with a more elaborate but less durable plastered form. Some superstructures were furnished with a small channels in the center of the eastern side, apparently to discharge rainwater from inside the plastered floor of the superstructure that was framed with a raised border (Kulicka 2011: 491). This feature must have dealt with the excess rainfall of a long Alexandrian winter season.

In parts of the cemetery the walking level around the superstructures was covered with a layer of yellow sand a few centimeters thick; this brings to mind the sand surrounding some superstructures of the Lower Necropolis (see above, *§ 2.5.1*). Layers of yellow sand were also discovered on the earth floors of grave boxes from this phase (Kubiak 1967a: 49).

Tombs of the Upper Necropolis were sometimes grouped together, possibly as family complexes (Simpson 1995: 244), surrounded by low enclosure walls. A semicircular niche found frequently in the inside face of the south wall of these enclosures may be interpreted as a *mihrab* (Dzierżykray-Rogalski 1969: 105–106).

Departures from the general form of graves described above were possible but very rare. Two atypical substructures were discovered in Sector CV (CV-161 and CV-163). They were exceptionally big, barrel-vaulted, and had steps leading from the shaft to the chamber. Similar structures had been found earlier in Sectors C (C-12) (Kołątaj 1976: 224, 227) and AW (T-98) (Kulicka 2016: 62, Fig. 24).

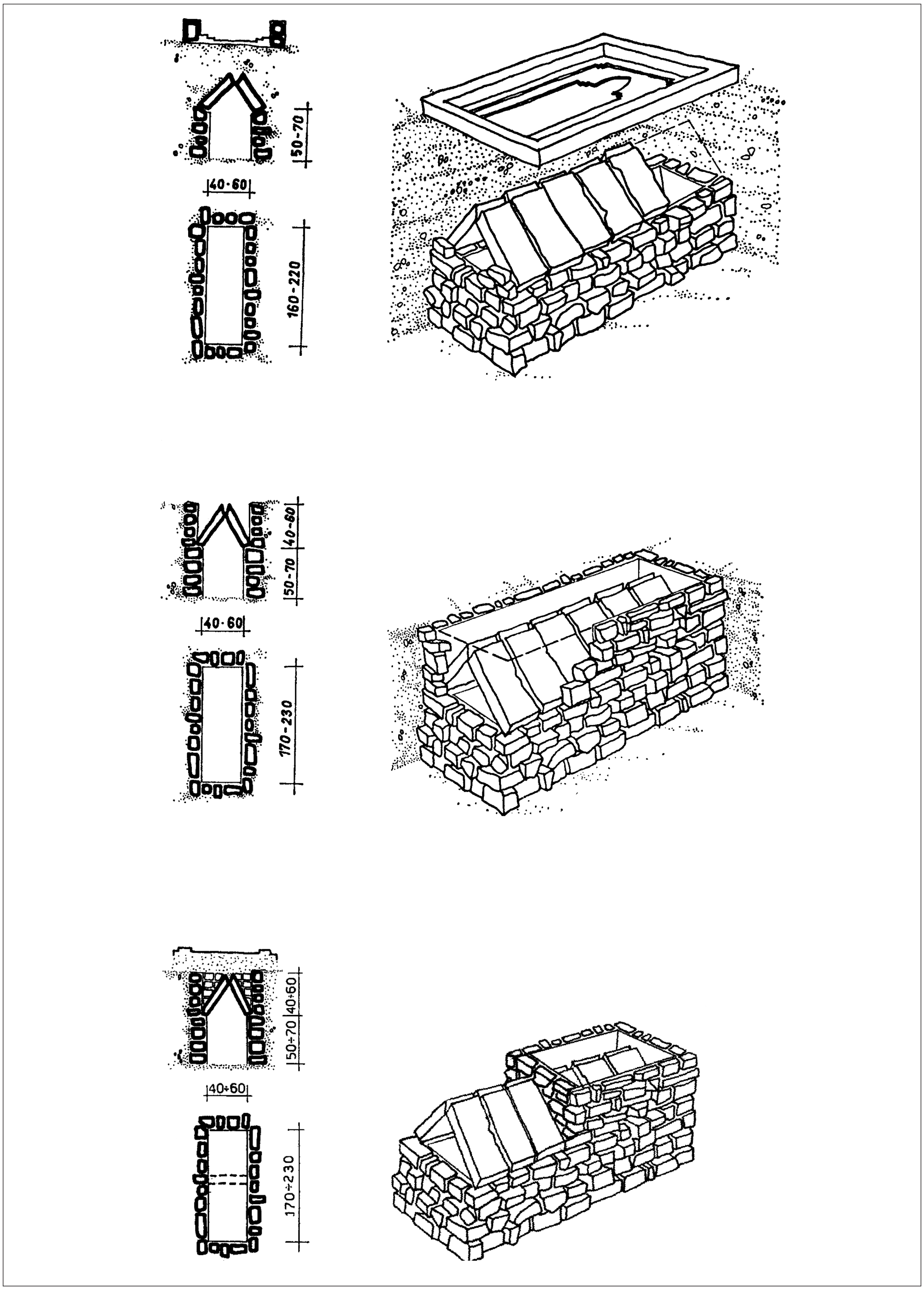

Fig. 22. Typical substructures of the Upper Necropolis; the topmost example presents a plastered superstructure in the form of a *mihrab* (After Kubiak 1967a: Fig. 4 and Kołątaj 1976: Fig. IV)

2.6 Cemetery extent

Remarks on the extent of the cemetery in the two phases are made here factoring in the gaps in the record, the scope of work accomplished to date and questionable issues discussed earlier, keeping in mind also missing data, like section of the site destroyed by an accidental explosion of gunpowder in the Kom el-Dikka fort grounds in 1889 (Hogarth and Benson 1894: 18; for the extent of the damage, see Kołątaj 1976: Pl. III) as well as modern construction work in the late 1950s.

The Islamic burial ground in question seems to have been included in its entirety within the so-called Tulunid fortifications built from scratch in the mid 9th century around a quarter of the area of the ancient Roman metropolis [see *Figs 1*; *23*], but the actual boundaries of the cemetery remain unknown. The occasional survey and chance discoveries made outside the area covered by the regular excavation project give the impression of vastness. It was also not the only Islamic burial ground in Alexandria, there being at least one other place set aside for burial inside the early Islamic defense walls—the main city cemetery located near Bab el-Ahdar, where the pious and the respected were interred in monumental structures surrounded by colonnades. The place is identified with today's Kom el-Nadura (Rodziewicz 1982: 40, 42). According to Rodziewicz (1982: 42), graves similar to those of the Lower Necropolis on Kom el-Dikka were found in a small salvage trench a few hundred meters northeast of the site. Remains of a cemetery were also noted in a pit dug for modern building construction outside the walls, east of the Rosetta Gate (Bab Rashid). Kubiak (1998) traced a more numerous and much more extensive area occupied by the cemeteries [*Fig. 23*] without, however, citing the grounds for his reconstruction.

Significant circumstances may have stood behind the otherwise unusual location of graves inside city walls:

1. Christian graves were scattered all over Alexandria from the late antique period until the Arab conquest (Fraser 1993: 100).
2. Since the burial ground lay north of the ancient L'2 street when the fortifications were being traced (the street may have been incorporated into the plan of the defenses as an inner circuit street running alongside the walls), it may have been impractical to change the regular course of the walls just to keep the cemetery outside.
3. The plan may have been also to develop the city, not just surround it with walls, hence incorporating the cemetery grounds left space for future development.

When looking at the plans reproduced herein one should keep in mind that they were generated for the two phases separately and out of necessity reflect not only facts from the past but also the excavation strategy on Kom el-Dikka. With regard to the Lower Necropolis [*Fig. 24*], the exploration frequently desisted on the pavement of the porticoes and the floors of the late antique complex. While the substructures were usually dug into the pavements of these buildings and were often *de facto* below the layers that were the main focus of the excavation, some data may yet wait to be collected. Thus, the plan of the Lower Necropolis reproduced in *Fig. 24* shows in color and with the use of symbols not only the graves and architecture but also the status of particular areas. In the case of this early phase only substructures are marked, not the superstructures (formerly identified as the Middle Necropolis) despite the chronological unity of the two. Superstructures of the Lower Necropolis are presented graphically on a wider-area plan [*Fig. 25*] and together with the Upper Necropolis [*Fig. 26*], as excavation of the later tombs usually involved the uncovering of superstructures of the

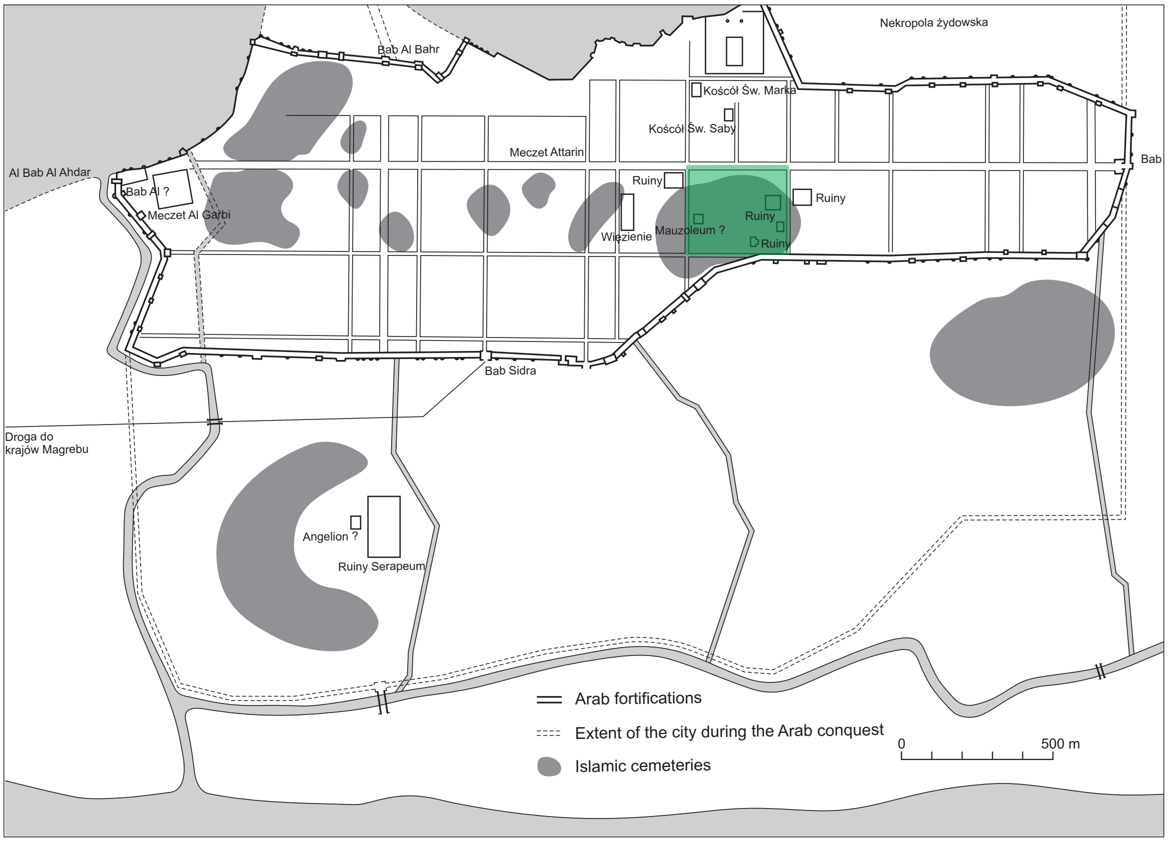

Fig. 23. Plan of Alexandria with the location of the Islamic cemeteries; green highlights the quarter of streets where the archaeological site of Kom el-Dikka is located (After Kubiak 1998: Fig. 1)

previous phase as they were in most cases on more or less the same level. It was much higher than the occupation level of the antique buildings, therefore the superstructures of the Lower Necropolis, perceived previously as belonging to the separate Middle Necropolis phase, were explored even if the substructures belonging to the same phase were not.

2.6.1 Lower Necropolis

The following general conclusions concerning the Lower Necropolis can be drawn on the grounds of the plan in *Fig. 24* keeping in mind the reservations described above:

1. The density of the tombs in the western part of the site is much bigger than in the eastern part.
2. Tombs do not cross the line of the late antique lecture halls and do not climb onto the slope of the later Kom el-Dikka.
3. Tombs were not located within the late Roman baths (with a few singular exceptions).
4. The burial ground in the first phase does not cross the eastern boundary set by the ancient street R4, beyond which were the remains of houses and shops from the Arabic period, built in place of dismantled late antique domestic architecture; the area was inhabited until the 10th century (Rodziewicz 1982: 38, 40).
5. Tomb orientation is fairly uniform, although Sectors U and AN show some deviations from the standard.

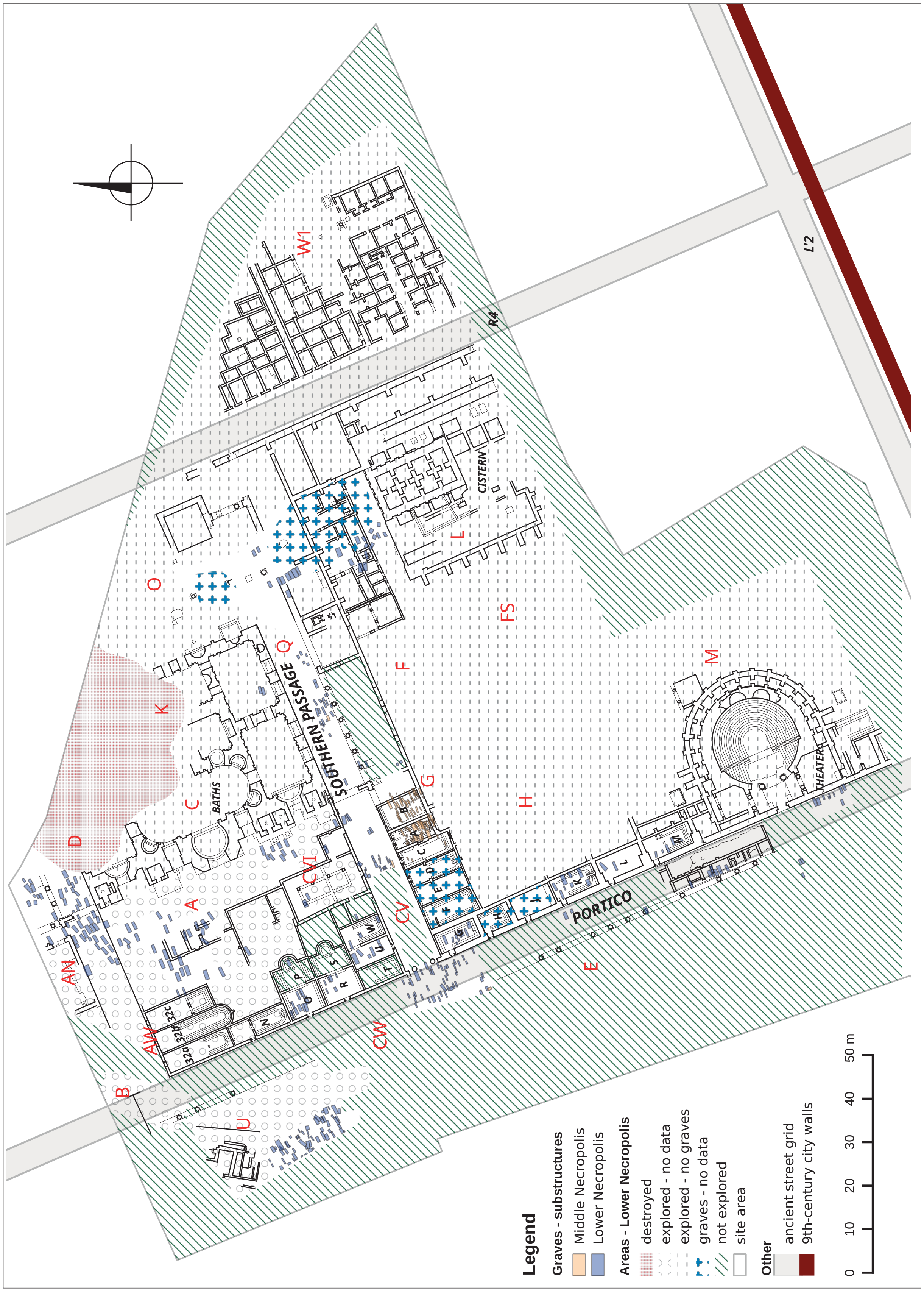

Fig. 24. Plan of the site with the location of grave boxes of the Lower Necropolis; hatching represents the state of research within given sectors of the site (Middle Necropolis structures on the plan should now be read as belonging to the Lower Necropolis phase)

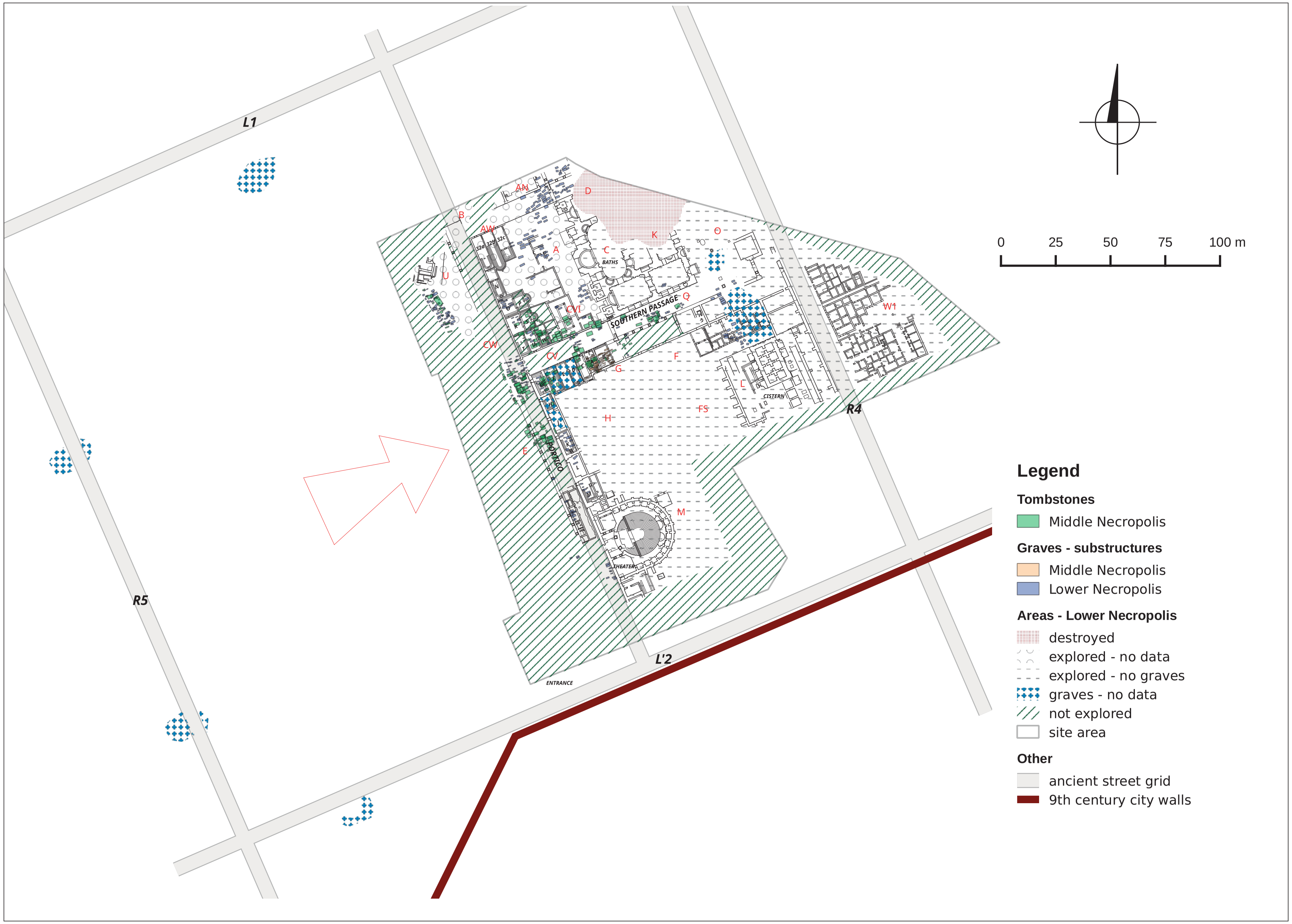

Fig. 25. Lower Necropolis: plan of the site within the quarter; arrow indicates the presumed direction of cemetery expansion (Middle Necropolis structures on the plan should now be read as belonging to the Lower Necropolis phase)

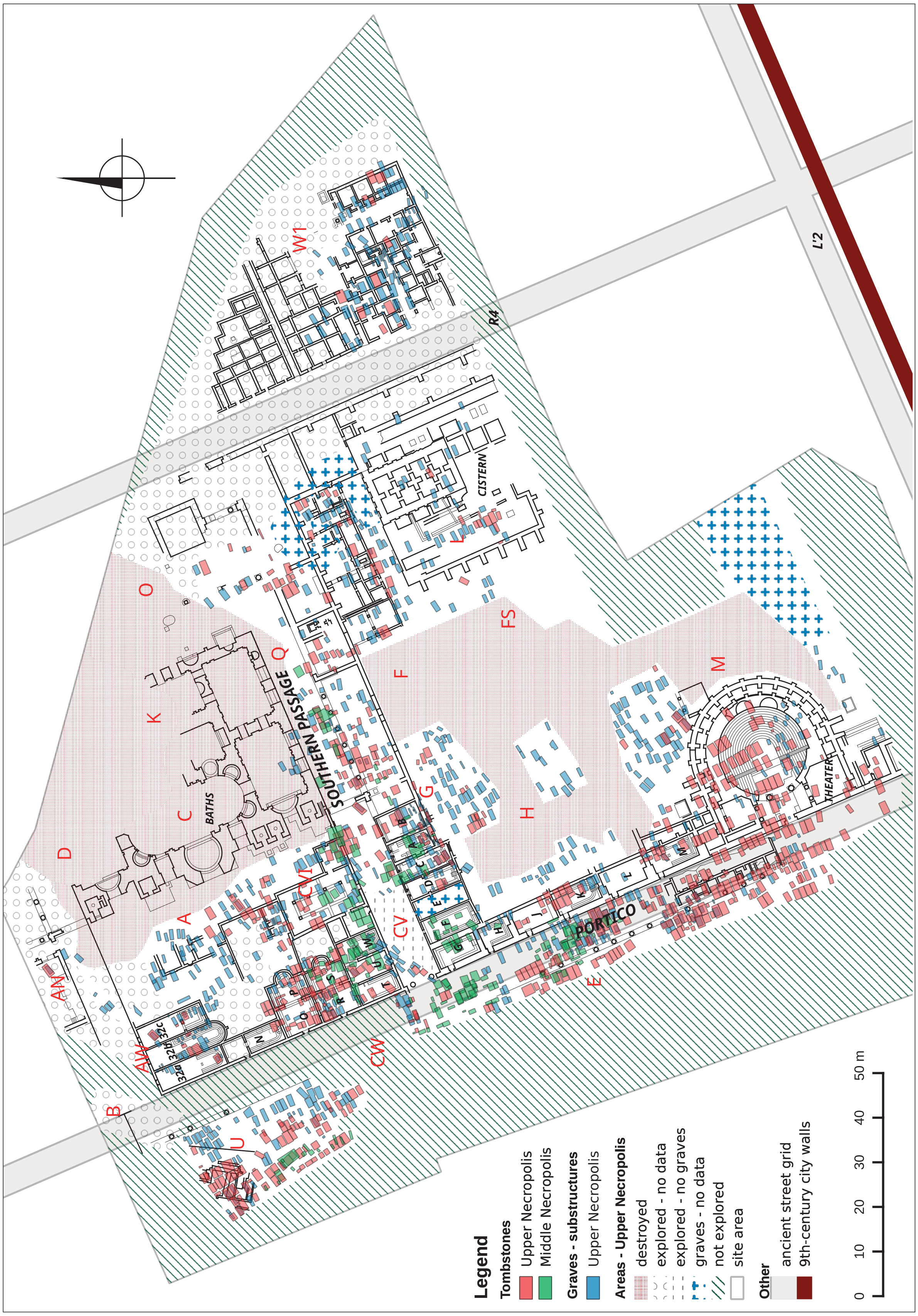

Fig. 26. Plan of the site with the substructures and superstructures of tombs from the Upper Necropolis, together with superstructures of the Lower Necropolis, previously interpreted as the Middle Necropolis (hatching marks state of research within given sectors of the site)

The noted deviation in tomb orientation, in Sector U at least, could have been determined by the distance from the standing ruins of the late antique academy used as a convenient reference by the gravediggers. In the case of the AN sector, it may well have been caused by another factor considered as more important, whether intuitively or consciously, namely, a structure that was cautiously interpreted as a small cemetery mosque (Rodziewicz 1978: 349, Fig. 1). The orientation of the tombs in Sector AN corresponds to the orientation of this structure, but it is not clear that it existed when the Lower Necropolis graves were being dug. It is also possible that the excavator dropped this early interpretation of the structure, because he does not return to it in his later publications of work at this site (Rodziewicz 1984a: 240–241; 1991: 75).[16]

The superstructures of the Lower Necropolis (former Middle Necropolis) show the greatest variability of orientation [see *Figs 9, 25*]. These are primarily the structures that were constructed above the outer walls of the lecture halls, running parallel to and opposite the walls with the entrances, hence at some distance from the adjoining porticoes. The incomplete elevation data did not bring anything certain to the analysis. All that can be said for now is that these "twisted" superstructures could be generally younger than others. They may represent the latest activity of the Lower Necropolis, at a time when not only the walls of the late antique academic complex were no longer visible on the surface, but also most of the nearby superstructures had disappeared as well.

The area taken up by the Lower Necropolis evidently extended beyond the borders of the site and most likely also beyond the boundaries of the quarter of the ancient city open to excavations [*Fig. 25*]. Its actual extent is not to be established in the present stage of research, but one can say that:

1. In the east, the graves of the Lower Necropolis most likely did not cross the boundary set by street R4.
2. In the north, it is quite probable that they did not stretch beyond street L1.
3. In the south, they stopped at street L'2, in the section that adjoined the medieval fortifications, because it is highly unlikely that they would have crossed the boundary established by the newly built defenses of the mid 9th century.
4. Tombs noted by Rodziewicz southeast of L1, a few hundred meters northeast of the site limits (Rodziewicz 1982: 42) and similar to the Lower Necropolis grave boxes in form, were most likely not connected with the cemetery under discussion here, especially if we remember street R4 as an impassable barrier for funerary structures in this phase.
5. The first graves must have most probably occupied the extensive square that stretched west of the late antique academy; from there they started to expand in every direction, gradually cutting into the ancient architecture to the east, but stopping eventually at the outer walls of the public complex.

2.6.2 Upper Necropolis

The observations concerning spatial relations of the graves within the Upper Necropolis phase as seen through data presented on the plans [*Figs 8; 26*] can be reduced to the following general remarks:

1. Tomb orientation in this phase is much more variable than in the case of the substructures of the Lower Necropolis, but the general direction remains unchanged; the variation

[16] The second cited publication is a reprint, of worse quality, of the first article.

observed may be because the ancient walls were most probably no longer visible above ground everywhere to provide an easy reference.

2. The superstructures of these tombs show less variability regarding orientation than the subterranean parts; the aboveground markers were relatively wide and in many instances arranged in rows, the longer sides parallel to one another (a situation well visible in sectors M, E, and U). The substructures were narrower and not openly visible, hence the chances that they would not be exactly parallel were greater. In the case of grave boxes, any deviations that occurred could not offend the eye, being obviously hidden underground.
3. Part of the tombs in sectors CV and CW are oriented in a completely different way, running in a narrow band at an angle across the Southern Portico.
4. Deviations from the standard orientation are observed again in Sector AN, perhaps owing to the presence of a structure other than the late Roman baths, as intimated already above.
5. The burial ground in this phase covered practically the entire excavated area of the site, including the huge rubbish dump that had formed as a small hill in the central part (Sectors H, G, F, and M); tombs were located also in the area of the monumental late antique structures, in the theater and the cistern, although the density of graves covering the lattermost structure seems to be lesser than in the other parts of the site.
6. The late Roman baths continued to be avoided; similarly as in the case of the Lower Necropolis, singular graves encroached only on the fringes of this area.
7. The devastation of the layers of the Upper Necropolis was much more extensive that in the case of the Lower Necropolis, which does not come as a surprise in the context of earthworks that destroyed late layers in the first place, carried out in the area within the frame of modern revitalization programs.
8. On the up side, a much larger area of the burial ground from this phase was uncovered due to the focus on the late antique architecture, which required the planned removal of all superimposed layers (the substructures of the Lower Necropolis were for the most part below the late antique occupation level).
9. The tombs of the Upper Necropolis are quite evidently much more numerous and their arrangement is much denser compared to the earlier phase.

A good reason why graves are practically absent from the area of the late Roman baths is the relatively good state of preservation of the ruins in this period. By the time the Upper Necropolis started to be frequented, the other public buildings in the area had disappeared under mounds of sand, rubble and pottery waste that formed a hill behind the row of lecture halls. Already in the late antique period the area had been used to dump ash removed from the heating furnaces of the nearby baths. Accumulation of deposits in this area led to their extended spreading until they covered the adjacent ruins and piled up against the standing ruins of the cistern and theater edifice. The bath, however, was located on the other side of the Southern Portico, and its walls, still standing very high in the early Islamic period, may have protected it from being fully covered. An alternative explanation for the almost total absence of graves within the walls of the bath is the partial destruction of the early Islamic layers in this place, hence the lack of data.

The burial ground in this phase started to occupy much more space also outside the boundaries of the archaeological site on Kom el-Dikka, in the wider context of the ancient urban quarter [*Fig. 27*]:

1. Tombs of the Upper Necropolis crossed the previously impassable eastern boundary set by street R4.
2. On the south, tombs spread across street L'2, possibly beyond the city walls, but it is impossible to be sure whether the graves noted outside the line of the fortifications (a grave box observed by the author in a modern building trench), although similar in form, were part of this or an entirely different cemetery.
3. On the west, as before, the Upper Necropolis crossed the line set by street R5.
4. On the north, it stopped again most probably before the line of street L1.

2.7 Cemetery evolution

Burials in the cemetery on Kom el-Dikka, at least within the boundaries of the archaeological site explored by the Polish team, can be divided into two chronological phases:

- Lower Necropolis – from the beginning of the 9th to the first half of the 10th century,
- Upper Necropolis – from the second half of the 11th to the end of the 12th century.

In this context, the Middle Necropolis should be interpreted as an integral part of the Lower Necropolis.

The revised phasing was prompted by anomalies observed by the author in the distribution of age-at-death frequencies of the individuals buried in the Kom el-Dikka cemetery, and credible phasing has been deemed crucial from the point of view of the bioarchaeological part of this study. Upon reviewing also the archaeological evidence, it turned out that combining the Lower and Middle Necropolises from the previously commonly accepted three-phase chronology created a culturally credible whole, a Lower Necropolis, better fitted to the chronology given by funerary stelae, which were the only solid dating category of finds, even if mostly from secondary contexts, forthcoming from the burial ground.

The data also demonstrated a need to move the dating of the first tombs to a time horizon well dated by the inscriptions on funerary stelae that were previously thought to belong to the middle of three phases. The Arab conquest is for obvious reasons a border date for the first burials, whereas the second border date is the earthquake of 796, some 150 years later (frequently quoted in the literature as 792). The cataclysm may have finally obliterated the remains of late antique Alexandria, at least to the point that enabled the installation of a cemetery within the ruins of the late antique public complex. Therefore, the earliest burials could have taken place on Kom el-Dikka in the end of the 8th and in the early 9th century. This phase could have ended in the first half of the 10th century, a time of war, civil unrest and relatively frequent earthquakes. The coming of Fatimid rule in Egypt in 969 may be cautiously considered as a border date for the functioning of the first phase of the burial ground.

During the great famine around the mid 11th century, Kom el-Dikka—within the borders of the archaeological site—again became a funerary site. The density of the tombs, the area they occupied, the number of burials and the evident artistry of the craftsmen building them attest to

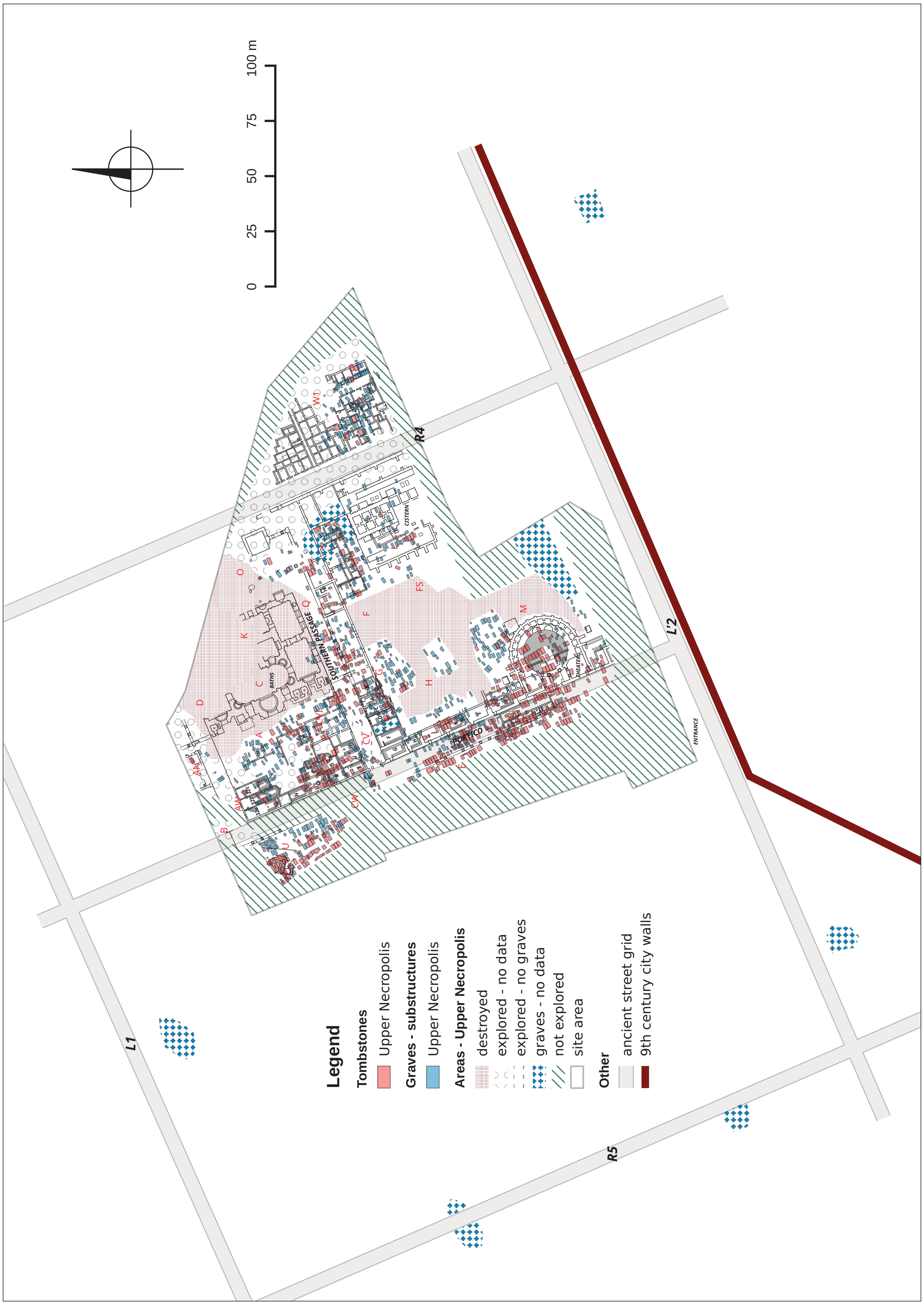

Fig. 27. Upper Necropolis: plan of the site within the quarter

the development and prosperity of Fatimid Alexandria. Decline came most probably with the changeover from Fatimid to Ayyubid rule. The last isolated burials may have been interred there as late as in the first half of the 13th century.

Supplementing the above with a fairly distinct stratigraphic gap between the Upper Necropolis and the burial phase(s) that preceded it and without sound premises for separating the Middle Necropolis from the Lower one, a division into two instead of three phases seems only reasonable. Future excavations on Kom el-Dikka, carried out with thee assumptions in mind, could yet provide more substantial evidence for a more detailed picture.

Appendix
Plans used in this study

Unpublished plans

Plans kept in the documentation of the Polish Centre of Mediterranean Archaeology University of Warsaw (unless stated otherwise). Individual items present the following information in sequence:

No.	Sector/Locus or Unit	[Season]	PCMA archive no.: author
Lower Necropolis			
1.	AS/O	[2010]	ALEX.2009–2010.001t: A.Kotarba, digitizing E. Kulicka
2.	CV/W	[2016]	ALEX.2016.001t: E. Kulicka
3.	CW/U, W	[2006]	ALEX.2005–2006.002t: E. Kulicka
4.	CW/R	[2011]	ALEX.2011.001t: E. Kulicka
5.	G/G	[2005]	ALEX.2004–2005.003t: U. Wicenciak, digitizing E. Kulicka
6.	H/L	[2002]	ALEX.2002–2003.008t: digitizing E. Kulicka
7.	H/K	[2003]	ALEX.2002–2003.006t: D. Elkowicz, digitizing E. Kulicka
8.	M	[2001]	ALEX.2000–2001.005t: G. Majcherek, digitizing E. Kulicka
9.	M/M	[2002]	ALEX.2001–2002.004t: G. Bąkowska, digitizing E. Kulicka
10.	M/M	[2002]	ALEX.2001–2002.005t: G. Bąkowska, digitizing E. Kulicka
11.	Q	[2004]	ALEX.2003–2004.006t: E. Kulicka
12.	U/W	[2014]	ALEX.2014.001t: E. Kulicka
Middle and Upper Necropolis			
13.	68 (middle)	[1968]	ALEX.S.A.047t
14.	AN (upper)	[1981]	ALEX.S.A.049t: M. Barański?
15.	AS/O-P (upper)	[2002]	ALEX.2002–2003.001t: G. Majcherek, E. Kulicka
16.	AS/O-P (upper)	[2002]	ALEX.2002–2003.002t: G. Majcherek
17.	AS/O-P (upper)	[2002]	ALEX.2002–2003.003t: G. Majcherek, E. Kulicka
18.	AS,CV (upper)	[2003–2006]	ALEX.S.A.050t: A.Pisarzewski, G. Majcherek, E. Kulicka

19.	CV (middle)	[1984]	ALEX.1983–1984.003t: G. Majcherek
20.	CV/W (middle)	[2015]	ALEX.2015.003t: E. Kulicka
21.	CV (upper)	[1998]	ALEX.1997–1998.002t: G. Majcherek, A. Talar, digitizing E. Kulicka
22.	CV/W (upper)	[2015]	ALEX.2015.001t: E. Kulicka
23.	CV/W (upper)	[2015]	ALEX.2015.002t: E. Kulicka
24.	CW/R-W (middle)	[2006]	ALEX.2005–2006.001t: E. Kulicka
25.	CW/W (middle)	[2006]	ALEX.2005–2006.005t: E. Kulicka
26.	CW (upper)	[2005]	ALEX.2005–2006.003t: A. Pisarzewski, digitizing E. Kulicka
27.	CW/R (upper)	[2011]	ALEX.2011.002t: E. Kulicka
28.	E (middle)	[2002]	ALEX.2002–2003.004t: A. Szczepanik, digitizing E. Kulicka
29.	E (middle)	[2005]	ALEX.2004–2005.001t: M. Woźniak, digitizing E. Kulicka
30.	E (middle)	[2005]	ALEX.2004–2005.002t: M. Woźniak, digitizing E. Kulicka
31.	E (middle)	[2007]	ALEX.2006–2007.001t: E. Kulicka
32.	E (middle)	[2007]	ALEX.2006–2007.003t: E. Kulicka
33.	E (upper)/south	[2001]	ALEX.2000–2001.001t: A. Pisarzewski
34.	E (upper/middle)	[2002]	ALEX.2001–2002.001t: G. Bąkowska, digitizing E. Kulicka
35.	E (upper/middle)	[2002]	ALEX.2001–2002.002t: G. Bąkowska, digitizing E. Kulicka
36.	E (upper/middle)	[2002]	ALEX.2001–2002.003t: G. Bąkowska, digitizing E. Kulicka
37.	E (upper)	[2007]	ALEX.2006–2007.002t: E. Kulicka
38.	G/G (middle)	[2005]	ALEX.2004–2005.005t: M. Woźniak, digitizing E. Kulicka
39.	G (middle)	[2005]	ALEX.2004–2005.004t: M. Woźniak, digitizing E. Kulicka
40.	G/H-east (upper)	[2001]	ALEX.2000–2001.002t: I. Zych, digitizing E. Kulicka
41.	G–H (upper)	[2007]	ALEX.2007–2008.001t: A. Brzozowska
42.	H/J (upper)	[2001]	ALEX.2000–2001.003t: I. Zych, digitizing E. Kulicka
43.	H/K (upper)	[2003]	ALEX.2002–2003.007t: T. Pelc, digitizing E. Kulicka
44.	H/L (upper)	[2003]	ALEX.2002–2003.005t: T. Pelc, digitizing E. Kulicka
45.	H/H (upper)	[2004]	ALEX.2003–2004.001t: E. Kulicka
46.	H (upper)	[2004]	ALEX.2003–2004.002t: E. Kulicka
47.	H (upper)	[n.d.]	ALEX.S.A.045t: W. Kołątaj, digitizing E. Kulicka
48.	L/SW (upper)	[2006]	ALEX.2005–2006.004t: E. Kulicka
49.	M (upper)	[1999]	ALEX.1998–1999.001t: M. Łukowska
50.	M (upper)	[1999]	ALEX.S.A.046t: M. Łukowska, A. Kaczor, A. Pisarzewski
51.	M (upper)	[2000]	ALEX.1999–2000.001t: A. Kaczor, digitizing E. Kulicka
52.	M (upper)	[2000]	ALEX.2000–2001.004t: digitizing E. Kulicka
53.	M (upper)	[2000]	ALEX.1999–2000.002t: A. Kaczor, digitizing E. Kulicka
54.	M/M (upper)	[2002]	ALEX.2001–2002.008t: G. Majcherek, digitizing E. Kulicka
55.	M (upper)	[2002]	ALEX.2001–2002.006t: G. Bąkowska, digitizing E. Kulicka
56.	M (upper)	[2002]	ALEX.2001–2002.007t: G. Bąkowska, digitizing E. Kulicka

57.	M (upper)	[1964–1967]	ALEX.S.A.048t: A. Ostrasz, W. Kołątaj, J. Nalewajski (Holder: Institute of Mediterranean and Oriental Cultures, Polish Academy of Sciences)
58.	Q (middle)	[2004]	ALEX.2003–2004.005t: E. Kulicka
59.	Q (upper)	[2004]	ALEX.2003–2004.003t: M. Krawczyk
60.	U/NS (middle)	[2013]	ALEX.2013.002t: E. Kulicka
61.	U/W (upper)	[2013]	ALEX.2013.001t: A. Kubicka, E. Kulicka, K. Majdzik
62.	U (upper)	[n.d.]	ALEX.S.A.051t

Published plans

The most important general plans [G] and plans covering small sections [D] of the cemetery used in this study in their published form:

[G] **Dąbrowski 1966**: Figs II, III
Plans divided into two phases from the first trench excavated in the burial ground at the beginning of the regular archaeological exploration of the site.

[D] **Dzierżykray-Rogalski 1966b**: Plan V
Test trench H, surveyed by W. Kołątaj, appended to this article by mistake as it should have illustrated a report by J. Lipińska and H. Riad (1966), included earlier in the same volume.

[D] **Lipińska 1966**: Fig. III
Test trench F.

[D] **Promińska 1968**: 79
Upper Necropolis southeast of test trench F, surveyed by W. Kołątaj.

[G] **Kołątaj and Kołątaj 1975**: Pls 1–2
Plans of the Lower and Upper Necropolis within the area of the theater building and in its immediate neighborhood, drawn by A. Ostrasz, W. Kołątaj and J. Nalewajski.

[G] **Kołątaj 1976**: Pls I–III
Necropolis around the bath divided into three chronological phases.

[D] **Rodziewicz 1984a**: Fig. 3
Upper Necropolis in Sector U.

[D] **Rodziewicz 1984b**: Fig. 147
Graves dug into the layers overlying villa B in Sector W1.

[G] **Meyza 2000**: Pls IV–X
Two plans by Wojciech Kołątaj, Jarosław Dobrowolski and Krzysztof Kamiński, including graves of the Upper and Middle Necropolis and five plans picturing the five phases of the necropolis distinguished during the excavations in Sector G.

[G] **Tkaczow 2000**: Pls XIV–XV
Two plans presenting outlines of burial features from the Lower and Upper Necropolis respectively, encompassing all of the ancient quarter with the archaeological site (and its immediate neighborhood).

[D] **Rysiewski et al. 2000**: Figs 19, 21, 22
Graves of the Middle and Lower Necropolis in Sector CS.

Excavation documentation used in this study

No.	Sector	[Year]	PCMA archive no.
GRAVE REGISTER NOTEBOOKS			
1.	G, M	[1985–1987, 1999–2001]	ALEX.S.A.053t
2.	Q, CV	[1997]	ALEX.S.A.054t
3.	E, H, M	[2002]	ALEX.S.A.055t
4.	AS, CW, E, G	[2005]	ALEX.S.A.056t
GRAVE RECORDING SHEETS			
5.	G	[1985–1987]	ALEX.S.A.057t
6.	AN, AS, AW, C, CV, D, L, U, W2	[1974–1984]	ALEX.S.A.058t
7.	CS, CV, CW, E, G, H, L, U	[2006–2016]	ALEX.S.A.052t

Chapter 3

A BIOARCHAEOLOGICAL APPROACH

Changes in the living conditions of the group of people burying its dead on Kom el-Dikka can be studied from various angles, for example historical and material. Nonetheless, the extensive set of data on human bone remains collected from the site to date enables also a bioarchaeological approach.

Bioarchaeology is a term that was first used in 1972 by British prehistorian Sir John Grahame Douglas Clark in reference to zooarchaeological studies (Larsen 1997: 3). By 1977 it had been adopted by American anthropologist Jane E. Buikstra to describe research on human remains in archaeological studies (Wright and Yoder 2003: 43–44; more recently, e.g., Larsen and Walker 2010: 379). In European science, it is frequently used to refer to the study of all organic remains (not only human) in archaeological projects, whereas "osteoarchaeology" or rather "human osteoarchaeology" or "human bioarchaeology" (Larsen 2014) is a counterpart of what American science tends to designate as bioarchaeology.[1] The terms are used here alternately (refraining from a deeper discussion of the scope of each) and only in relation to human remains, as reflected by the nature of the material and the research question.[2] Since only teeth and bones are available for study (the soil conditions at the site are not conducive to the preservation of organic remains), therefore the narrowing of perspective offered by the "osteo-" prefix is, generally, not at odds with the substance.

Definitions of "anthropology", the third term evoked in this work, are extremely varied and fairly broad at times, but in this book the term is used to address the community of working field archaeologists, of which the author deems himself part, which is accustomed to refer thus to the discipline engaged in the study of the biological characteristics of human bones from archaeological excavations.

The twofold nature of human remains, biological and cultural, in archaeological contexts (Agarwal and Glencross 2011: 1) affords the opportunity of looking at changes in the living conditions of the Alexandrian population in light of the historical transformation shaping the environment and social reality of the city. The archaeo-historical background of these changes has been discussed above; how they affected the wellbeing of this population is considered in this part. The bioarchaeological perspective calls for different indicators of the wellbeing of a skeletal population being compared with reference material. In the case of the Kom el-Dikka burials, the best reference for the Lower Necropolis from a bioarchaeological perspective is a sample from the Upper Necropolis, allowing a clear view of potential diachronic changes taking place in Alexandria between the 9th–10th and the 11th–12th centuries.

The methodological part of this study covers all the issues deemed important from the point of view of the discussion that follows. However, the most attention is given to methods of stature reconstruction, stature being a highly ecosensitive attribute and as such the best singular indicator of the wellbeing of a population. Together with basic paleodemographic characteristics, that is, sex and

[1] For a history of bioarchaeology as a field of study, see also Larsen 2018.

[2] The faunal remains, which have been published rather incidentally so far in the context of the cemetery on Kom el-Dikka (Dzierżykray-Rogalski, Promińska, and Rodziewicz 1972), were reasonably assumed by the excavators to represent urban refuse, a layer of which thickly blankets the burial ground. There is no specific evidence of a relation with either the tombs or any kind of funerary ritual, hence the decision not to include faunal remains in this study.

age-at-death, it forms the core of the reasoning herein. The emerging picture of change is supplemented with data on caries, which have the potential of reflecting dietary change, and two popular physiological stress indicators: tooth enamel hypoplasia and *cribra orbitalia*, which present the effects of various factors influencing the lives of the studied individuals at different stages of ontogenesis.

3.1 Earlier research

Reconstructions of the medieval society of Alexandria based on anthropological data have been undertaken before. Investigations on the subject were initiated by Tadeusz Dzierżykray-Rogalski, who was particularly interested in paleopathological issues (Dzierżykray-Rogalski 1977; Dzierżykray-Rogalski and Promińska 1985; 1992). He was joined in the research by Elżbieta Promińska, author of the first broader summary of research on the Islamic cemeteries of Kom el-Dikka (Promińska 1972).

The age-at-death data from the Kom el-Dikka burials, drawn from the publications of Dzierżykay-Rogalski and Promińska, led the demographer Edmund Piasecki to construct a stationary population model for Alexandria (Piasecki 1975). This research, like the studies of Dzierżykay-Rogalski and Promińska, was conducted at a time when analyses of large data sets were extremely time-consuming and multi-aspect approaches were all but impossible. Promińska rounded off a lifetime of investigations with a comprehensive study of human growth, comparing data collected from the skeletal sample with modern medical data (Promińska 1985). No other studies after 1985 undertook the challenge of a broader view of the biological condition of the dead from Kom el-Dikka in a specific historical context.

Raw data from two seasons of excavation at the necropolis in the 1986 and 1987 seasons were published 15 years later by Henryk Rysiewski in a volume dedicated generally to the outcome of the excavation project, but avoiding more general interpretations (Rysiewski 2000). After 1987 the mission did not have an osteologist on the staff for almost two decades, one reason for this being concentration of the work on earlier phases of site occupation. For a number of seasons after 1999, when the excavation of the cemetery was resumed, the skeletal remains were collected and placed in storage. In 2004, anthropologist Karol Piasecki joined the project, bringing in the present author as an assistant osteologist in the autumn of that year.

The author took over from Piasecki as an independent specialist in 2007, publishing a few partial analyses of his own work, but without the relevant catalogs of data (Mahler 2007; 2012). The most recent season of anthropological research at the site in 2014 was carried out with Urszula Okularczyk in assistance (Mahler and Okularczyk 2016). The author is currently continuing research on the collected data and remains part of the PCMA UW Alexandria excavation project.

3.2 Osteological material

Work carried out at the Kom el-Dikka site in Alexandria since the 1960s has resulted in some 2340 graves having been examined to date; at least that is the number of grave units included in the database. The actual number of units that were excavated in the intervening years, or rather those that were originally located in the excavated area, cannot be determined because of gaps in the documentation, especially from the 1970s, which are impossible to fill today.

Human remains from 940 grave units were available for anthropological analysis, but only in 725 units, that is, about 77% of the cases the remains could be correlated with archaeological data. The remaining 215 graves with bones could not be identified in the available documentation. To date, no less than 2603 individuals have been distinguished among the human remains collected from the site; in the case of 248 individuals, it was possible to gather odontological data in addition to analyzing the bones. The uncertainty as to the actual number of individuals in the studied set is rooted in the limitations of macroscopic anthropological methods, which can give only an estimated value in the case of commingled burials. The number of 2603 individuals represents the minimum number of individuals (MNI) recognized in the data, using a procedure described, for example, by Tim D. White (2000: 354). MNI was determined separately for the material from each grave context that was presumed not to have been mixed with material from other archaeological contexts.

3.2.1 Sample

Five anthropologists (including the present author) have done osteological research on the Kom el-Dikka human remains, applying methodological approaches relatively independent of the region, culture and chronology. However, this means five different methodical approaches, perhaps even more assuming that researchers working for many years with the material from a given site are subject to a changing understanding of the material and may adapt and transform their approaches as a result of an evolution of the science and/or a new methodological base. Tracing the evolution of scientific approaches proved impossible to incorporate into the present discussion.

The results of anthropological analyses were sorted, standardized and entered into an electronic database, the architecture of which was prepared by the author. The database was created from a combination of different sources, sometimes mutually contradictory. Some of the data was expectedly either lost or never collected, but it was quite unfeasible to provide any estimates in this regard. Relevant available information is summarized below, making an effort to identify errors in the collected data (for a more extensive discussion of the sources of error, see below, *§ 3.3.11*). The total number of individuals recorded in the database was reached by combining all of the available data:

1. 1583 of the burials were examined by anthropologists Dzierżykray-Rogalski and Promińska. The former participated in the work at the site practically from the beginning of the project, that is, from 1962, the latter began in 1964 and worked most probably through 1981 inclusively. Individual data was published in two monographs (Promińska 1972; 1985) and nine articles, the latter consisting chiefly of data collection reports (Dzierżykray-Rogalski 1962; 1963; 1966a; 1966b; 1968; Dzierżykray-Rogalski and Promińska 1968; 1970; 1971; Promińska 1968);
2. 272 of the burials, explored between 1984 and 1987, were examined by Rysiewski in 1986–1987 and the individual data were published in 2000 (Rysiewski 2000);
3. 38 individuals were examined by Karol Piasecki in 2004 (data collected as field notes);
4. 710 of the burials were studied by the present author starting from 2004; the data were published in part in aggregated form (Mahler 2007; 2012), the part from sector U as individual data (Mahler and Okularczyk 2016).

The singularity of this data set determines its exceptional value, while significantly narrowing usability. It is, as already indicated, the only set of Muslim burials in such numbers from the early Islamic period—from Egypt or from anywhere else in the immediate region—to be studied systematically from an osteological point of view.

There are no other series available for comparison and reaching for studies from, for example, distant Spain (Moreda Blanco and Serrano Noriega 2008), even assuming that comparable data is available, would not clarify to any greater extent the changes that the medieval community of Alexandria experienced. Of some interest are the results of an osteological study of the skeletal series from excavations in Quseir al-Qadim on the Egyptian Red Sea coast. The series, however, consists of a relatively small sample of 85 skeletons (Macklin 2004), while the late dating and specific location en route on the pilgrimage road to Mecca makes it impossible to use these results as comparative material in this analysis.[3]

3.2.2 Data completeness and quality

The accuracy of the data from Kom el-Dikka is dependent on a number of factors. The generally poor state of preservation of the bones is a source of error that is not easily quantifiable. In many instances, the bones have all but disintegrated due to the high salinity of the depositional environment combined with frequent immersion in water, rainfall being frequent in this part of Egypt (Kulicka 2008: 45, 47; 2010: 49). Bone fragmentation, especially evident in the case of graves with multiple burials from the Upper Necropolis (sometimes a dozen or so individuals in one grave), was another factor reducing the research potential. Moreover, burials from this phase, which is chronologically the youngest and consequently, at least theoretically, the best preserved, have yielded extensively commingled and heavily fragmented human skeletal material as a result of specific burial practices, namely, the unceremonious pushing aside of earlier remains to make room for new burials, which led to the crushing of the older bones. In such instances, only the most recent interment was found in anatomical arrangement (Kulicka 2008: 46–47; 2010: 50, 54; Promińska 1972: 12). Deteriorating parts of tomb structures and pits excavated for new tombs added to the overall poor state of preservation of the bones.

Laborious reconstruction of shattered long bones and skulls was often the only way to collect measurement data. This was particularly true of skeletons from the Lower Necropolis, where the state of preservation of the bones was the worst. The following key factors, largely independent of the osteologists working on the project, affected data completeness:

- bone excavation procedures: not enough time in the field for bone preparation and retrieval of the smallest skeleton parts (at Kom el-Dikka freshly uncovered bones are wet as a rule and need to dry off before collection; skulls and the joint areas of long bones need to be cleared with extra care when still wet, drawing out the time needed for the procedure);

[3] The life of the inhabitants of a cosmopolitan Alexandria on the Mediterranean coast would in all likelihood differ substantially from the life of members of a small community that formed on the Red Sea coast, on a road frequented by pilgrims. The genetic and environmental factors that played a key role in the formation of their perceived biological characteristic would have been very different and any reconstruction of these factors is beyond the scope of the present study.

- priorities in staff deployment: in a project focused on excavation of late antique architecture, professional osteologists were hardly part of the essential field staff;
- selection of bones for analysis: as a rule, non-specialists acting in lieu of professional osteologists took decisions concerning bone exploration and collection for analysis without sufficient knowledge of the osteological research potential;
- quality of and changing storage solutions, on the whole a detrimental factor: decalcification of bones stored in bags and boxes made of acid paper; mixing of the bones from packaging chewed apart by rodents getting at the natural glue used in the production; bones stored in plastic bags becoming brittle and useless for reconstruction, if not properly dried beforehand.

3.2.3 Published data

Most of the data collected by anthropologists working on Kom e-Dikka has been published (see also *§ 3.1*), but consistency has suffered over the years and observations have most certainly been lost. Estimating the losses is difficult for lack of archival data, but the following has been ascertained:

- part of the data on unpublished burials from before 1972 is lost; the existence of this data is attested in Promińska's 1972 study and some of these burials were published in a catalog accompanying her 1985 study; data on other individuals with no long bones to measure were not considered at the time, although one can assume by analogy with her other works that not only those with long-bone lengths were taken into account in the field analyses;
- Promińska's 1985 study also informs indirectly of analyses made between 1972 and 1985 (the latest data concern skeletons excavated in 1975; see Promińska 1985: 190–191), which were not published even in the rudimentary form presented in her 1972 study (the next set of published data is from 1984–1987, see Rysiewski 2000: 99).
- unknown number of burials that were never studied by osteologists for a myriad of non-professional reasons, especially at least a hundred graves explored in Sector U before 1985 (Rodziewicz 1985, but with no information on any analyses of the bone material).

Ultimately, the database used in this study contains published data coming from the analysis of altogether 1855 skeletons.

One should also bear in mind the vicissitudes of publishing in an age before computer desktop layout. On one hand, printed data is expected to have been checked and revised by authors, and presented in clear and legible tables. On the other hand, revisions before the use of computers were not an easy task and changing table format, illustration numbers or chapter sequence, could result in chaos. Many errors accompanied the correction stage, while poor print quality reduced the legibility of the illustrations. Errors noted in publications sourced for the present study were corrected whenever possible. Some information could be compared with successive publications, other data were described twice within a single publication, in the catalog as well as tabular lists, therefore enabling comparison between the two. Also, the anatomically improbable values were identified when encountered, like the incorrectly described rows recognized in a measurement table in Rysiewski's publication (2000).

3.2.4 Unpublished data

Errors in print can be corrected, if the original documentation is available for comparison, which is not the case with the material from Kom el-Dikka. In the past, specialist analyses, like anthropological research, only exceptionally made it to archival shelves (even archaeological data sometimes did not find enough space). The bulk of raw data and the photographs, especially in the age before the "digital revolution", was kept in private hands and were not usually made available to anyone but the owners. Families were rarely responsible depositaries of these collections in the case of the poor health or after the death of a researcher, and the data ended up presumably in the rubbish. The ultimate fate of the documentation made by Dzierżykray-Rogalski, Promińska, and Rysiewski is unknown.

Original notes on 38 skeletons were given to the author by Karol Piasecki, and for the remaining 710 skeletons, it is the author's own research. The author's set is also the only one that can be used as a source of consistent odontological data with the reservation that the data from the 2004 season does not reflect the modifications to selected methods introduced by the author in his second season at the site the next year. Some of the observations of the dentition in individual cases made in 2004 were of a general character; later, each tooth and tooth position were evaluated separately.

Handwriting, which is the prevalent form in which the data were recorded, causes much difficulty and is a source of error (even the author had problems with his own handwriting on occasion). In addition, Piasecki's notebook lacked structuring of the records; in his case, a fill-in form would have greatly facilitated the process of reading the data. Database entries made from handwritten notes amounted to a total of 748 records of bone analyses and 248 records of odontological observations. Apart from selected data from Sector U, these observations have not been published before.

3.3 Methods

The author's goal in this study is to track changes in living conditions as demonstrated in the osteological material in correspondence with the historical processes known to have taken place in Alexandria between the 9th and 12th centuries. The subject of comparison are two populations living in the same city and possibly of the same ancestry and very similar cultural background. Being faithful to the conviction that the best way to use statistical inference is to keep it as simple as possible, the author has resorted first of all to the simplicity of descriptive statistics and supplemented it with basic statistical tests to compare proportions and averages.

3.3.1 Data acquisition and standardization

The bioarchaeological analysis within the frame of this study was focused on human bones and teeth, which were for the most part the only biological remains to be preserved in the deposition conditions of the Kom el-Dikka site. Soft and epidermal tissues, like hair and nails, may have been missed in exploration, but looking at the deposition conditions of the soil, it is much more likely that in most cases they simply were not preserved.

It has already been indicated when discussing the osteological material above that the author marshaled data from both his own research and from both published and unpublished project data. Procedures employed for the study of each of the categories as well as essential data unification are described below.

3.3.1.1 *Own research*

A thorough anthropological analysis of the remains was preceded by laborious and time-consuming: cleaning, sorting and reconstruction of the bones. Mechanical cleaning was chosen over washing with water because of the observed high salination and erosion of the bone material. Severe fragmentation of diagnostic skeletal elements hindered the evaluation, necessitating bone reconstruction using an adhesive, a procedure which was not facilitated by the brittleness of the fragments and a significant diurnal variation of both temperature and humidity in the workplace affecting the properties of the adhesive as well as of the bones themselves. The effort at bone reconstruction was well justified in view of the number of measurements that could not have been collected otherwise.

The methodology applied was largely a factor of the state of preservation of the bones and the logistical and financial means of the project, effectively translated into the necessity of reburial of the remains directly after completing the analyses. The methods that were selected balanced the workload against the expected results, the goal being to collect the broadest possible spectrum of observations. The range of methods answered to the challenges encountered by the author during the ten years of work for the project and his growing experience and expert knowledge as an bioarchaeologist. Nonetheless, for the sake of consistency, the scope of collected data was not modified significantly in any way, keeping in mind, on one hand, sustained comparability with the sets produced by earlier researchers and, on the other, the need to keep the set short due to time constraints imposed by external circumstances.

Ultimately, the anthropological analysis consisted of:

- determining a minimum number of individuals (MNI) separately for each tomb, taking into consideration morphological differences (White 2000: 291–292);
- sorting commingled remains (Brothwell 1981: 16–17; White 2000: 291);
- charting state of preservation of the skeletons in graphic form (Brickley and McKinley 2004), and in descriptive form for aspects not included in the charts;
- sex determination using a set of morphological methods (Buikstra and Ubelaker 1994: 16–21; Piontek 1996: 127–141; White 2000: 362–371);
- age-at-death determination using a broad range of commonly applied macroscopic methods:

FOR ADULTS:

- dental wear, using tables construed by C.O. Lovejoy (1985: 49–50);
- changes in the pubic symphysis according to Todd (1921; 1920), after Piontek (1996: 168–169), and Suchey and Brooks (1990), after Buikstra and Ubelaker (1994: 23–24);
- changes of the auricular surfaces of the ilium, according to Meindl, Lovejoy and others (Lovejoy et al. 1985; Meindl and Lovejoy 1989), after White (2000: 355–359);
- cranial suture fusion (Buikstra and Ubelaker 1994: 32–35);
- overall view of skeletal morphology (including changes to the sternal end of the 4th rib [Bass 1995], general picture of degenerative changes, etc.);

FOR CHILDREN:

- prime method of age evaluation taking into account tooth formation and eruption according to tables construed by D.H. Ubelaker (1978, 47), after Piontek (1996: 144–145);
- long bone shaft measurements whenever teeth and dental arches were not available for examination; determining approximate age-at-death based on tables prepared by M. Stloukal and H. Hanákova (Piontek 1996: 143), P.S. Gindhart (Piontek 1996: 146) and L.A. Dmitrienko (Piontek 1996: 147); using in doubtful cases tables of bone development and ossification by T. Marciniak (Piontek 1996: 147);

FOR ADOLESCENTS (and very young adults):

- degree of epiphyseal fusion used as the main age determinant (Piontek 1996: 148);
- collecting data for a reconstruction of body morphology (Brothwell 1981; Malinowski and Bożiłow 1997; Pearson 1899; Strzałko 1971): height, shoulder-to-pelvic width proportions etc., based on long bone measurements (length, circumference, width of shafts and epiphyses, diameters and circumferences of heads). Measurements followed generally accepted standards (Buikstra and Ubelaker 1994; Martin and Saller 1959);[4]
- collecting data for a morphological evaluation of the skull: measurement of chords (Buikstra and Ubelaker 1994; Malinowski and Bożiłow 1997) and basic descriptive characteristics (Piasecki 1992);
- collecting data on the so-called epigenetic characteristics, allowing a general evaluation of the biological distance between populations (Alt 1997; Buikstra and Ubelaker 1994; Piontek 1996); some of these should indeed be interpreted as environmental instead of hereditary, that is, reactions to long-term external factors connected to, for example, profession or intentional deformation;
- collecting data for evaluating health condition and possibly diet (paleopathological observations and other), including:
  - changes on joint surfaces signaling a degenerative disease (Buikstra and Ubelaker 1994; Rogers and Waldron 1995);
  - caries, enamel hypoplasia, tartar, crown wear observed on teeth (Alt, Rösing, and Teschler-Nicola 1998; Caselitz 1998; Hillson 1996; Smith 1984);
  - porotic hyperostoses (Buikstra and Ubelaker 1994);
  - other changes of a pathological nature (Roberts and Manchester 2005), aiming at a verifiable diagnosis (Aufderheide and Rodriguez-Martin 1998; Ortner 2003; Waldron 2009).

Not all of the collected data and observations have been used in this study. The catalog presented in the Appendix contains only the information that was actually analyzed.

Skeletons excavated in Sector U in the fall season of 2014 are an exception from the above. In their case, a shortened data collection form was used, refraining from a detailed description of the state of preservation and a detailed examination of the skulls, which were not reconstructed at the time. For the skulls, only their general shape was taken into consideration and that only with

[4] For a list of the most useful measurements with references to the most popular textbooks, see Brickley and McKinley 2004: 30. However, caution is advised when using this list as the measurements of tibia length are marked incorrectly.

respect to the characteristics essential for sex determination. C*ribra orbitalia* changes were also recorded (Mahler and Okularczyk 2016).

3.3.1.2 *Published data*

The acquisition and digitizing of structuralized information was onerous but not difficult. The first step was to transfer published records as completely and as faithfully as possible, any required transformation of the data being left to the data-unifying stage. The changes introduced at this stage were meant to eliminate errors and adapt records to a form typical of digital sets.

The difficulty with the numbering of the graves was resolved by unifying the system across the site. Original markings were retained as much as possible to ensure secure reference to documentation and publications. For easier identification, individual burials (skeletons) were also given discrete markings, unique in the Kom el-Dikka system.

Major errors in the case of records with skeleton measurements were relatively easy to spot. They were eliminated wherever possible. The following is a list of noted errors.

- The sequence of rows in table 2.0 with the skull measurements in Rysiewski's publication (2000: 114–115) was corrected, establishing the proper order thanks to the characteristic ranges of each of the chords. To find the proper descriptions in the enclosed legend, one needs to add 10 to the number of rows 24 to 40 (i.e., 34 would become 44 etc.), whereas for rows 41–50 one needs to subtract 17 (i.e., 45 would become 28 etc.).
- Faulty attributions to cemetery phases were corrected by linking anthropological data with archaeological records considered as the more credible ones, at least with regard to the phasing.
- The exceptionally low measurement of 13 for the older individual, No. 1, from grave 1968-12/68 could attest to errors in the *id–gn* values given by Dzierżykray-Rogalski and Promińska. The *id – infradentale* point disappears with the lowering of the alveolar part, which is what happened probably in the case of this individual. The low height of the mandible at the point of measurement was most probably due to the obliteration of the alveolar part after the tooth had fallen out, not surprising in an individual estimated to have been 55 years old or more at death. If the alveolar part is only slightly lowered, the measurement should include a reconstruction of the original value, but if it is impossible to reconstruct reliably the original value of an unchanged tooth socket (which was probably the case here), measurements should not be taken at all (Buikstra and Ubelaker 1994: 78; Martin and Saller 1959: 452, 481). This particular value was excluded from the set, but it raised doubts as to whether in the other instances the analyses reconstructed the measurement values where necessary. The same reasoning is true of the *n-pr* measurement using the *pr* – prosthion point, which is the counterpart of the *id* point on the maxilla (Buikstra and Ubelaker 1994: 75; Martin and Saller 1959: 449, 481).
- The numerical values describing "height of mandibular corpus" (a phrase used by the researchers in a few variants, both in English and in French) were interpreted as the *id–gn* measurement, in accordance with the data describing individual No. 1 from the set of bones from Sector M-IX, designated as M-1 by the authors of the analysis at the time for lack of any other identification on the bag (Dzierżykray-Rogalski and Promińska 1968: 209).

Ultimately, for reasons discussed below (*§ 3.3.2*), the skull measurement data were not used in this study and were therefore omitted from the catalog of burials. However, since the data were used during preliminary research on this material, a description of how the craniometrical data were digitized has been included here.

3.3.1.3 *Unpublished analyses*

The procedure for digitizing data from Piasecki's notes was the opposite of that adopted for the published data: there, only the data needed for the present study was digitized, that is, sex, age-at-death and bone measurements. The loose structure of the recorded information and difficulties with deciphering the handwriting were the main reasons. The number of records was relatively small (38 individuals), hence the data set could be unified provisionally and entered into the database without having to digitize all of the information beforehand.

3.3.1.4 *Data unification*

Several methodological issues had to be addressed when merging data sets produced over the course of many years. The most important was to determine if and to what extent data from different sources could be compared directly.

Sex, age-at-death and stature of the deceased constitute basic bioarchaeological characteristics. The order of the three is not arbitrary, because the latter two are dependent on the first. It is hardly convenient for both first and second determinations to be the result of applying methods of unknown accuracy (as indicated above, earlier researchers seldom even reported the methods used in their analyses). Despite an improved methodological base, modern determinations of sex and age-at-death are almost equally burdened with an unknown error. For example, the Phenice (1969) method, which is still the best singular way of determining sex based on skeletal characteristics, using pelvis morphology, yields from 59% to even 96% and 100% accurate assessment depending on the study (White 2000: 368). Beside an inter-population variability, the relatively poor state of preservation of the skeletons on Kom el-Dikka is another factor, the impact of which is difficult to estimate. In his own research, the author found that sex determination based on the pelvic bones was seldom an option. A handful of cases consisted of fragments of bone big enough for all three elements required by the Phenice method to be applied.

And yet, the metric data, a relatively very objective factor, paradoxically does not give equally reliable results (White 2000: 365–366). Discriminatory functions are dependent on sexual dimorphism, manifested by the size of selected elements of the skeleton for the population for which they were created. Consequently, since they are constructed based on a morphological evaluation of sex, because other data (e.g., from registers) for skeletal populations are usually not available, they add their own error to the errors resulting from these determinations. In this situation, discriminatory functions should be treated as an auxiliary measure and used only in cases where other methods have failed.

Moreover sex determination may be dependent on age-at-death (Lovell 1997: 118–119), which, considering that determination of the latter may be conditioned by the former, creates a feedback that may amplify the bias. In this context, it seems reasonable to accept sex determination of unknown accuracy, but taken from publications authorized by researchers of good standing, and include them in a data set originating from current analyses.

The same is true of age-at-death determinations, although it should be said that in the case of old age in particular (55 years and more), anthropology several decades back was overly optimistic as to the resolution of the applied methods. On the whole, it seems justified, assuming that relatively broad age brackets will be used in relevant statistical analyses, to include in the corpus of data discussed here determinations made more than 50 years ago in the form as is.

Age-at-death unification procedures called for transformation into age brackets with numerically expressed beginning and end. This solution permits later calculations, while reconciling a broad spectrum of different forms of source recording with an intuitive legibility of years of life. Only the youngest children and infants have lost some legibility in this system, owing to the need for using real numbers which are obviously different from the readers' everyday experience. The preference in this case would be for using months or weeks, or even days, but this would have violated the logic of the described solution.

Concerning long bone measurements, in the few cases in early publications when stature is the only value given, one can only guess at the method used to arrive at the specific estimate. In one of his early articles Dzierżykray-Rogalski (1962: 87) claimed to have used long bone measurements and a method introduced by Manouvrier (1892) for reconstructing stature; it is more than likely that he used the same method on other occasions as well. Such records are too few, however, to justify a reconstruction of "ideal" bone lengths that could have produced given statures. The potential error resulting from such a procedure, especially when using data thus obtained for estimating growth by another method, would be quite high.

The uncertainty of measurements and determinations used in the study was denoted using subjective uncertainty scales. These were objectified to some extent, taking on measurable values for metric data (see below, *§ 3.3.11*). It should be kept in mind, however, that in the case of sex, age-at-death and *cribra orbitalia*, the uncertainty accompanying verdicts will reflect the measure of the researcher's conviction regarding the uncertainty of a particular assessment.

Data from analyses of the dentition were also collected in the database, but it proved impossible to unify them for the whole set. Prior to 2005 the main focus was apparently on anomalies, foregoing on a separate assessment of each individual tooth and tooth socket.

The paleopathological observations used in this study, similarly as the odontological data, could not be unified for the whole set. The degree of *cribra orbitalia* could be determined as a numerical value for only one individual in analyses other than those made by the present author.

3.3.2 Testing the data

The preliminary age-at-death analysis of the individuals buried in the Kom el-Dikka cemetery was carried out on a unified but not verified data set. The anomalies noted then became even more apparent once the set was verified [see *Fig. 18*], prompting a review of the phasing of the burial ground and its dating and the subsequent decision to propose a revised historical frame for the archaeological and anthropological conclusions.

Table 6. Skull indices used in the preliminary analysis. Names in the 'Index' column and equations in the 'Formula' column given after Bass (1995: 68–82) and Malinowski and Bożiłow (1997: 182–187). All labels with the exception of the last one constructed based on a numerical representation of measurements according to Martin and Saller (1959: 453–479), preceded in the equations by the letter M (in parentheses)

Label	Index	Formula	
8:1	Cranial Index (CI)	$\frac{eu - eu \ \text{(M8)}}{g - op \ \text{(M1)}} \times 100$	(1)
17:1	Length-Height Index	$\frac{ba - b \ \text{(M17)}}{g - op \ \text{(M1)}} \times 100$	(2)
17:8	Breadth-Height Index	$\frac{ba - b \ \text{(M17)}}{eu - eu \ \text{(M8)}} \times 100$	(3)
9:8	Fronto-Parietal Index	$\frac{ft - ft \ \text{(M9)}}{eu - eu \ \text{(M8)}} \times 100$	(4)
48:45	Upper Facial Index	$\frac{n - pr \ \text{(M48)}}{zy - zy \ \text{(M45)}} \times 100$	(5)
48:46	Upper Facial Index by Virchow	$\frac{n - pr \ \text{(M48)}}{zm - zm \ \text{(M46)}} \times 100$	(6)
47:45	Total Facial Index	$\frac{n - gn \ \text{(M47)}}{zy - zy \ \text{(M45)}} \times 100$	(7)
52:51	Orbital Index	$\frac{sbk - spa \ \text{(M52)}}{mf - ek \ \text{(M51)}} \times 100$	(8)
54:55	Nasal Index	$\frac{apt - apt \ \text{(M54)}}{n - ns \ \text{(M55)}} \times 100$	(9)
MBH	Mean Basion-Height Index	$\frac{ba - b \ \text{(M17)}}{\frac{g - op \ \text{(M1)} + eu - eu \ \text{(M8)}}{2}} \times 100$	(10)

Skull morphology was explored as another tentative element of more extended research. Tests of the data did not reveal any statistically significant differences in the ten most commonly used indicators [***Table 6***] between the populations buried in the two phases of the cemetery, calculated separately for men and women [***Tables 7A–B***]. The comparison used a two-tailed t-Student test for two independent variables, with Welch's modification for series with different variance. For the calculations, a `t.test()` function, an R language implementation of t-test, was used. A visual evaluation of the frequencies of particular index values[5] [see below, ***Figs 28, 29***] found them to be more or less normal (see below), which is a prerequisite for applying the t-Student test.

[5] The considerable differences between the absolute value range of the Hrdlička-Kóčka index and that of the other indices necessitated a separate histogram in order to correctly visualize the variability of its value.

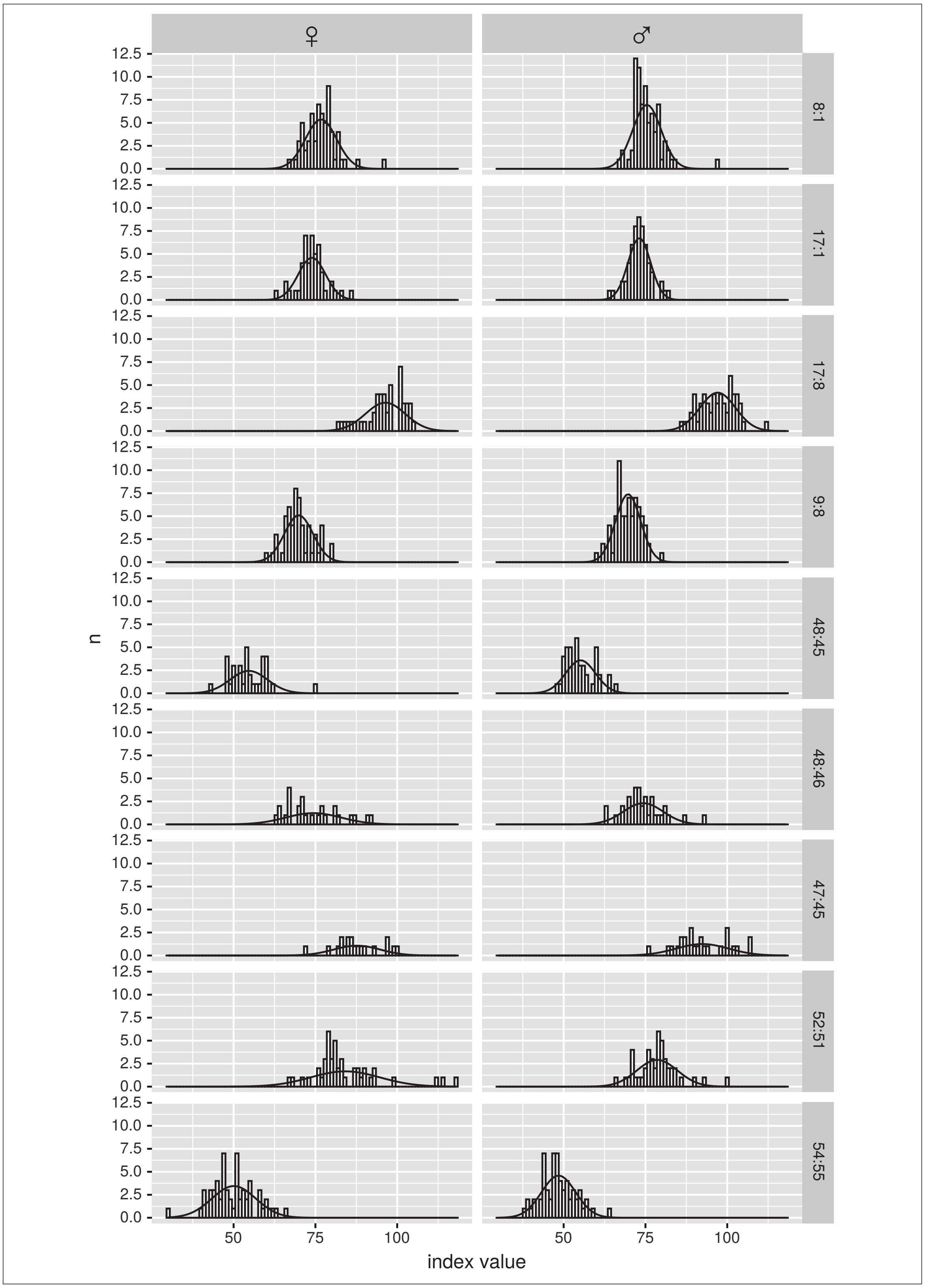

Fig. 28. Frequency distribution of the cranial indices for the individuals buried in the Upper Necropolis, taking sex into consideration

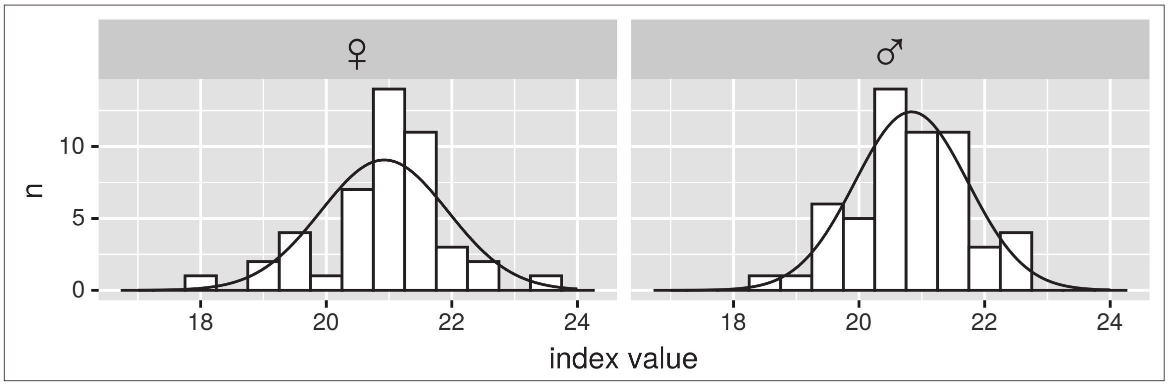

Fig. 29. Frequency distribution of the Mean Basion-Height index of the skull for the individuals buried in the Upper Necropolis, taking sex into consideration

Evaluation of normality was carried out only for the Upper Necropolis, for which the number of measurements is sufficient to enable effective imaging and even here, the reasonable arbitrary minimum of 50 measurements that was assumed as having the potential to produce readable histograms, resulted in only three of ten indicators reaching this threshold for women and six of ten for men. This had a negative impact on graph legibility. The results can hardly be considered as conclusive for the Virchow upper face index for females (48:46), where the series numbered 26, and for the morphological face indicator for both sexes (47:45), where the series counted 19 for females and 25 for males.

Serious doubts about normality are raised also by the apparently skewed histograms of the height–width indicator (17:8) for females and width–length (8:1) for males. They are relatively numerous, however: respectively 47 and 76 results. In keeping with the central limit theorem, since their numbers exceed the magic 30 (Ruxton 2006: 688), it may be cautiously assumed that the distribution of this sample is similar to normal (Sokal and Rohlf 1995: 132; Wikipedia 2020a). These frequencies should perhaps be studied more in the future, but for the purposes of the present study it is to be assumed that these data may also be tested in the above described manner without compromising the power of the test.

The skull index charts also show outlier values [see below, *Figs 28, 29*]. However, eliminating from the data set single values identified as extreme or, more justifiably, whole records concerning the skulls which are the source of these values, would result in a noticeable drop in numbers of the series. Extreme values largely affect averages, while it is mean skull indicator that is being compared here. It was decided, however, that the improved homogeneity of some series does not justify such a large drop in the number of all those taken into consideration. In addition, the negative impact of outliers was mitigated to some extent by applying the Welch correction to take into account the variances in calculations.

Upon examining the results, there is no reason to believe that a comparison of skull morphology by chord measurements would help to bring out the differences between the people of Alexandria buried in the Lower Necropolis and those who used the Upper Necropolis. Perhaps there were no morphological differences, which would be an important finding in itself. Nonetheless, in view of the limited data from the Lower Necropolis, the above hypothesis cannot be satisfactorily tested. It was decided therefore to exclude skull measurements from further consideration.

Table 7. Indices for skulls: A – female; B – male; comparison of mean values for the Upper and Lower Necropolis; n – number of index values available; $\bar{x}$ – mean index value; s – standard deviation; p – p value calculated using a two-tailed t-Student test for two independent variables, with Welch's modification for series with different variance; p_{adj} – p value adjusted for multiple comparisons using Benjamini-Hochberg's correction

A

	♀							
	Lower Necropolis					Upper Necropolis		
	n	$\bar{x}$	s	p	p_{adj}	n	$\bar{x}$	s
8:1	11	75.86	3.79	0.514	0.643	64	76.72	4.75
17:1	10	72.28	4.15	0.272	0.643	48	73.94	4.16
17:8	10	95.95	8.50	0.881	0.881	47	96.39	6.07
9:8	11	69.01	3.51	0.474	0.643	56	69.89	4.38
48:45	8	55.39	3.73	0.655	0.728	35	54.64	5.72
48:46	6	72.18	5.00	0.409	0.643	26	74.43	8.46
47:45	2	101.70	9.33	0.265	0.643	19	87.69	7.08
52:51	10	80.39	5.86	0.140	0.643	44	84.12	10.56
54:55	11	47.07	5.79	0.145	0.643	58	50.07	6.71
MBH	10	20.59	1.41	0.491	0.643	46	20.92	1.01

B

	♂							
	Lower Necropolis					Upper Necropolis		
	n	$\bar{x}$	s	p	p_{adj}	n	$\bar{x}$	s
8:1	10	78.35	4.98	0.108	0.540	76	75.46	4.36
17:1	9	74.81	2.03	0.055	0.540	58	73.13	3.43
17:8	9	96.59	7.92	0.862	0.993	57	97.08	5.44
9:8	10	67.69	5.59	0.296	0.987	71	69.70	3.83
48:45	6	55.18	3.69	0.993	0.993	41	55.17	4.55
48:46	7	74.20	6.43	0.961	0.993	35	74.33	6.05
47:45	2	91.50	1.13	0.619	0.993	25	92.41	8.01
52:51	5	78.00	4.00	0.785	0.993	45	78.57	6.17
54:55	10	49.07	7.08	0.800	0.993	60	48.46	5.22
MBH	9	21.07	1.08	0.553	0.993	56	20.83	0.90

3.3.3 Sex

Sex determination is the most important part of any osteological analysis, facilitating subsequent assessment of age-at-death and stature, and providing one of the most important characteristics for future analyses. Methods of sex determination have been presented above (*§ 3.3.1.1*) along with the justification for combining data from the author's research and published sources (*§ 3.3.1.4*).

The sex ratios were considered for each of the archaeologically distinguished groups. First, standard error of the obtained percentages was calculated [***Formula 1***]. Then degrees of freedom were calculated ($df = n - 1$) and a `t=qt(0.975,df)` critical value was read for a confidence level of 95% using the R function of the Student's t-distribution. The previously obtained *SE* was multiplied through this and the statistical error *d* of the ratio for a confidence level of 95% was obtained (Drennan 2009: 140–141).

$$s = \sqrt{p(1-p)}$$
$$SE = \frac{s}{\sqrt{n}}$$
$$d = t \times SE \qquad (1)$$

Where:

s : standard deviation of the sample;
p : proportion recorded as a decimal number;
SE : standard error;
n : sample size;
d : statistical error;
t : Student's t-distribution critical value.

Wherever there was need to compare the proportions obtained, the test χ^2 was applied following a procedure presented by Drennan (2009: 181–185) and using a version of the test without the Yates correction (Howell 2012: 147; Wikipedia 2020b), which was created for 2 × 2 contingency tables and is applied here only for tables with at least one cell with an expected size of less than 5 [***Formula 2***]. An `R prop.test()` function was used for this; it is particularly useful for testing the proportions with set expected values.

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \qquad (2)$$

Where:

χ^2 : value of the test statistic;
O_i : value measured for the *i*-cell of the frequency table;
E_i : expected value of the *i*-cell of the frequency table.

In addition to the comparison of sex ratios between chronological groups, the sex ratios of individuals buried in and outside the grave boxes was examined for both the Lower and the Upper Necropolis, this in order to take a closer look at other factors.

3.3.4 Age-at-death

Determination of age-at-death is a second, beside sex, key element of paleodemographic analyses, hence arriving at the most accurate indications has been at the core of the osteological methodology from the start. A comprehensive approach is now commonly accepted, in a version that is not formalized, assuming that the final determination is based on the largest possible number of detailed methods available (White 2000: 361–362). The advantage of this approach is the leeway to use the most appropriate methods in a given research situation, whereas the greatest weakness lies in the inability to evaluate with precision the uncertainty of the results. One way of dealing with this issue is the formulation of formalized complex multifactorial methods (Acsádi and Nemeskéri 1970: 122–135; Lovejoy et al. 1985: 3–4; Piontek 1996: 157–167), but still without fully satisfactory results (Cox 2000: 73–74).

The deficiencies of the methods can be accommodated at least in part by determining individual age-at-death as a range encompassing approximately the uncertainty of the age assessment itself. One should keep in mind that the precision of the determinations is further weakened by the broad age categories allowed by most of the methods, which is particularly evident in the case of adult individuals. Therefore, the lowest scale unit registering change observed for skeletons of adult individuals from Kom el-Dikka is no less than five years (except those on the verge of adulthood).

When determining age-at-death burdened with such high uncertainty, expressed by date ranges for individual verdicts covering sometimes a few dozen years, it is somewhat groundless to apply methods originating from demographic studies, although one could surely look for methods of this kind better suited to the study area.[6] Therefore, age-at-death brackets of a range other than the commonly used five years have been applied in the present paleodemographic analysis. They reflect the ontogenetic, that is, biological rhythm of human life rather than a purely chronological passing of years. Since developmental age brackets based on changes in the bones and in the dentition were also largely instrumental in formulating methods of skeletal age-at-death assessment, their use for subsequent inferences in this study was considered fully justified. Six age brackets were ultimately distinguished: *Infans I* (0–7), *Infans II* (7–14), *Juvenis* (14–20), *Adultus* (20–35), *Maturus* (35–55), *Senilis* (55–x).[7] The overlapping of the brackets is intentional, emphasizing the uncertain nature of the age-at-death assessment based on osteological material. To clarify the presentation in this study, the different age brackets will be referred to in the form of date ranges as given above, supplemented when deemed useful with terminology from common speech (i.e., "advanced age" meaning a biological assessment of age at 55+, "mature" at 35–55, "young adult" at 20–35, "adolescent" at 14–20, "late childhood" 7–14 and "early childhood" 0–7). In view of the fact that in most cases the age-at-death assessment of an individual was not limited to one of the age brackets, the share of a single skeleton in the sum total for a given category was frequently expressed as a real number. For the purposes of this study, share is defined as the probability of including the real age of a given individual, which is still biological and not chronological, in a given age bracket [*Formula 3*]. It follows that the sum of probabilities from all age brackets, calculated separately for each skeleton, will be equal to 1 [*Formula 4*]. Naturally, calculations will be correct only to the extent that the age assessment was carried out correctly.

The calculation [*Formula 3*] derives from the conviction that an age-at-death range determination, resulting from an individual analysis of a single skeleton, is in reality a range, in which

[6] While D.H. Ubelaker is seemingly correct in considering 20 years as the maximum sensible range of individual age assessment for use in a detailed demographic analysis (Ubelaker 1978: 46), a suitable selection and modification of methods combined with statistical modeling for larger series could bring satisfactory results (Cox 2000: 75).

[7] These brackets, drawn from the published work of Polish researchers (Malinowski and Bożiłow 1997: 303), aptly reflect, in the author's opinion, the assumed methodological choices made by successive Polish researchers working on this material since the 1960s. Differences with regard to the brackets most commonly used nowadays (Buikstra and Ubelaker 1994: 36; White 2000: 341–342) are solely in the details.

distribution of the probability of actual age-at-death is not in agreement with normal distribution. This is due to several and to some extent mutually dependent factors:

1) age-at-death frequencies for most historical populations do not demonstrate normal distribution;
2) resolution of age-at-death assessment methods depends on the age and sex of the individual;
3) the state of preservation of a skeleton introduces additional variability, as do the differences between the studied population and the model population used in formulating a method;
4) comprehensive age-at-death assessment in bioarchaeology as a term for a whole array of methods gives some leeway (White 2000: 361–362) as there is still no multifactorial meta-method available that would ensure satisfactory results in the case of individual assessments, while allowing for a comprehensive and formalized consideration of assessments made with arbitrarily selected detailed methods best suited to a given study material.[8]

Edmund Piasecki was of a different opinion regarding the form of distribution of the probability of the "actual" age-at-death appearing within the range indicated by anthropological evaluation. In his paleodemographic study based on the population buried in the cemetery at Kom el-Dikka, he used the Gausssian curve to indicate the specific age-at-death of individuals to be used in calculations. It allowed him to deal with age-at-death determinations given as ranges in the analyses published by Dzierżykray-Rogalski and Promińska (Piasecki 1975: 125–126). However, the irregular line charts with evident lows near the borderlines of divisions for developmental age (35, 55 years), especially for the male population (Piasecki 1975: Fig. 3), reveal the apparent deficiencies of this approach.

Rectangular distribution appears to better reflect the nature of the age-at-death evaluation in bioarchaeology. Therefore, for the sake of simplification it is assumed here after György Acsádi and János Nemeskéri (1970: 62) that the probability of an age being the real age-at-death is exactly the same for every possible age-at-death value, within a range constituting age-at-death assessment of an individual.

$$P_i = \frac{\dfrac{xp_i}{ep_i - sp_i}}{\displaystyle\sum_{j=1}^{n} \frac{xp_j}{ep_j - sp_j}} \qquad (3)$$

$$\sum_{i=1}^{n} P_i = 1 \qquad (4)$$

Where:

P_i	:	probability that the real age-at-death of the buried individual is in a given category bracket, assuming that biological age-at-death range was assessed correctly;
i, j	:	successive age-at-death category in the set of age categories covering the complete human life cycle;
sp	:	beginning of an age-at-death category bracket expressed in years;
ep	:	end of an age-at-death category bracket expressed in years;
xp	:	number of years in the age-at-death assessment range of a given individual in a given age category bracket.

[8] Promising efforts have been made in this matter (Anderson, Anderson, and Wescott 2010).

The sex ratios have also been considered in the context of the division into particular age categories. The impact of the summary sex ratio on the proportions for specific age categories was eliminated by multiplying the number of males, who had a superior percentage share in both phases, by the coefficient of the female-to-male proportion [*Formula 5*] calculated for each necropolis phase separately.

$$n_{\male ia} = n_{\male i}\frac{n_{\female}}{n_{\male}} \qquad (5)$$

Where:

$n_{\male ia}$: number of determinations of male sex in a given age category adjusted to compensate for uneven sex ratio in a given phase of the necropolis;

$n_{\male i}$: number of determinations of male sex in a given age category in a given phase of the necropolis;

$n_{\female}$: number of determinations of female sex in a given phase of the necropolis;

$n_{\male}$: number of determinations of male sex in a given phase of the necropolis.

3.3.5 Stature

Stature is highly eco-sensitive, hence its significance in bioarchaeological studies as a general measure of the wellbeing of human groups (Goodman and Martin 2002: 19–22; Larsen 1997: 13–19; Steckel 1995). The first step, however, prior to the actual analysis, is a credible reconstruction of life stature of individuals from their skeletal remains. This can be achieved in a number of ways. The easiest is to measure the body length in the grave, however the skeleton needs to be articulated, relatively undisturbed, in an extended position, preferably on its back (Gralla 1964; H.C. Petersen 2005). Such an ideal set of preserved characteristics is seldom encountered in archaeological practice. Another method, not restricted to undisturbed and specifically positioned skeletons, but which gives relatively accurate estimates, is the so-called anatomical reconstruction method (Fully 1956; Fully and Pineau 1960; Raxter, Auerbach, and Ruff 2006). This, however requires far more time and is only possible with very well preserved skeletons. Alternatively, and this is the most useful scenario in most bioarchaeological settings, life stature can be estimated from long bone measurements, which are routinely taken in the course of osteological analysis. The long bones constitute the largest part of an individual's height, therefore methods using bone length as a base for estimating life stature are the most reliable alternative, despite the uncertainty inherent in these estimations.

There is a wide variety of methods using lengths of long bones for reconstruction of stature. The method which performs best for individuals of an unidentified or largely uncertain morphotype is a simple femur-to-body-length ratio (Feldesman and Fountain 1996).[9] This would work best for the Kom el-Dikka series, for which—without addressing the usefulness and repeatability of morphotype determinations in osteological research—establishing a morphotype is not feasible in the bulk of cases (see *§ 3.3.2*). However, the overall poor state of preservation of the bones would result in very low counts of stature estimations if only the femur were used, therefore rendering the method

[9] A method developed by T. Sjøvold (1990) does not consider as essential the prior determination of an individual's morphotype or sex for stature estimation.

inadequate for this particular sample. In the case of the femur, stature estimations would be possible for only 156 skeletons, and with respect to 18 of these the results would be burdened with a high degree of uncertainty resulting from uncertain measurements. In view of this, the method of choice for the analysis would be the one which allows life stature estimations to be made from any one, given long bone measurement, thus making the best use of available data even from poorly preserved skeletons. To date, reconstructions of life stature of individuals buried in the cemetery on Kom el-Dikka have been made with one of four different methods of this kind:

1) that of Léonce Manouvrier (1892) applied by Dzierżykay-Rogalski and Promińska in their early work on osteological material from the site (mentioned in Dzierżykray-Rogalski 1962: 87);
2) that of Mildred Trotter and Goldine C. Gleser (Trotter and Gleser 1958; 1952) which Promińska used in her 1985 study of stature;
3) that of Karl Pearson applied by the present author in his studies (Mahler 2012; Mahler 2007);
4) that of Michelle H. Raxter et al. (2008), which the author used on the skeletal series from Sector U (Mahler and Okularczyk 2016).

Formulae developed by Raxter et al. (2008) were applied in the most recent publication of material from Kom el-Dikka (Mahler and Okularczyk 2016) on the exclusive assumption that the best formula to use for a population from Egypt is one that is closest to it, in time as well as geographical location. However, one should keep in mind that this method was based on skeletons originating for the most part from Old Kingdom Giza (89% both females and males in the sample) whereas barely 3% represented individuals (male only) from Roman-age Luxor, which is the closest chronologically to the medieval date of the Kom el-Dikka sample (Raxter et al. 2008: Table 1).

The method used most frequently by the present author in his work on skeletal material from Kom el-Dikka, and the one that till now he has considered the most appropriate stature reconstruction method for this set, is the Pearson method (1899). Despite the small size of the sample that Pearson had at his disposal when developing his equations, his method has been proven to be the most useful by M. Giannecchini and J. Moggi-Cecchi (2008) for the territory of Italy and by J. Kozak (1996) for Poland. In both instances, the method was found to produce the most consistent results for extensive series of individuals, including ones from the medieval period. These considerations should also be true for other populations which were shaped by similar living conditions (taking into account nutritional status, access to potable water, medical care etc.) and which shared a similar morphotype (Strzałko 1971). In view of the special status enjoyed by Alexandria in the studied period (see *§ 2.4*), it may be assumed intuitively that the medieval inhabitants of the city had more in common with the populations of other Mediterranean cities than with people living in other parts of Egypt. It is therefore tenable to consider Alexandria's population as closer in this respect to European populations, the medieval Italian series mentioned above in particular.

3.3.5.1 *Choice of stature reconstruction method(s) for the Kom el-Dikka skeletal series*

To verify this intuitive assumption, which led the author in his previous work to adopt the Pearson regression equations as best suited for the task of reconstructing life stature in the Kom el-Dikka series, a comparison was performed of the various methods. Following the line of the aforementioned research on the Italian and Polish series, the author compared the most commonly used regression equations in terms of the consistency of results obtained from a reconstruction of individual stature based on the length of various long bones. It should be made clear that this form of verification does not actually compare the accuracy of reconstructions by different formulae, but is intended rather as a means of selecting formulae that were constructed on measurements from a sample morphologically the closest to the population under study. Putting it this way, any potential differences that would be observed would be due solely to the mutual proportions of the length of the limbs and their constituent parts.

3.3.5.2 *Methodological framework*

For the present study, both the most common and the newest methods of stature reconstruction applied to archaeological remains from Egypt and based on measurements of long bones were taken into consideration. These were the three methods already used for the Kom el-Dikka material, that is, Pearson's, Trotter and Gleser's,[10] and Raxter's, plus one recently developed method by C.B. Ruff et al. (2012), which is one of the most comprehensive but still geographically focused methods.[11] The only method used previously (before 1985) in research on the Kom el-Dikka skeletal assemblage, but missing from the list, is the one developed by Manouvrier. The original publication of the method (Manouvrier 1892) contained only tables without presenting any regression formulae for use in the calculations. However, the method appears to be reflected to some extent in Pearson's slightly later formulae, mainly because his considerations were based on the same body of measurement data collected by Étienne Rollet (Manouvrier 1892: 227; Pearson 1899: 178–179; Rollet 1888).

In these methods, Pearson as well as Trotter and Gleser formulated linear regression equations based on bones from the autopsies of previously measured cadavers. Methods by Raxter and Ruff derived stature estimations from skeleton-based anatomical body reconstructions. The constituent components of the equations, all following standard linear regression formula [*Formula 6*], have been assembled in ***Table 8***, as provided by their respective authors.

$$y = bx + a \qquad (6)$$

Where:

y : stature estimate of an individual (in cm);
b : non-standardized regression coefficient (slope);
x : predictor – long bone measurement (in cm);
a : intercept.

[10] Including the correction applied by Trotter and Gleser to their method in the case of a regression formula for the radius of the Black female group (Trotter and Gleser 1977: 355). In the method by Trotter and Gleser, the names of morphotype variants are taken from White 2000: 372. The biological and cultural significance of these labels is not under discussion here due to the purely technical application of these methods.

[11] For the sake of simplifying the argument, the following abbreviations have been used here: Pearson – regression formulae developed by Pearson (1899: 196–197), Trotter (b) – regression formulae by Trotter and Gleser (1977: 355; 1952: 495) for the Black group, Trotter (w) – as previously, for the White group, Trotter (a) – regression formulae by Trotter and Gleser (1958: 120), for the East Asian group, Trotter (m) – as previously, for the Mexican group, Raxter – regression formulae developed by Raxter et al. (2008: 150), and Ruff – regression equations by Ruff et al. (2012: 606). Abbreviations used for bones: H – humerus, R – radius, U – ulna, Fem – femur, T – tibia, and Fib – fibula.

Table 8. Regression formulae used in the calculations; method referred to by the last name of the first author of the formula: Pearson – regression formulae developed by Pearson (1899: 196–197), Trotter – regression formulae by Trotter and Gleser (1977: 355; 1958: 120; 1952: 495), Raxter – regression formulae developed by Raxter et al. (2008: 150), and Ruff – regression equations by Ruff et al. (2012: 606); Group – names of morphotype groups in the method by Trotter and Gleser (after White 2000: 372); Bone – as appropriate: humerus (H), radius (R), ulna (U), femur (Fem), tibia (T), and fibula (Fib); Measurement – measurement number according to Martin and Saller 1959: 532–542, 561–577; Slope – regression coefficient; Intercept – intercept in the regression equation [see *Formula 6*]; *SEE* – standard error of the estimate

Method	Group	Sex	Bone	Measurement	Slope	Intercept	*SEE*
Pearson		♀	H	M1	2.754	71.475	–
Pearson		♀	R	M1	3.343	81.224	–
Pearson		♀	Fem	M1	1.945	72.844	–
Pearson		♀	T	M1	2.352	74.774	–
Pearson		♂	H	M1	2.894	70.641	–
Pearson		♂	R	M1	3.271	85.925	–
Pearson		♂	Fem	M1	1.880	81.306	–
Pearson		♂	T	M1	2.376	78.664	–
Raxter		♀	H	M1	2.83	70.94	2.73
Raxter		♀	R	M1	2.51	96.73	4.06
Raxter		♀	Fem	M1	2.34	56.99	2.52
Raxter		♀	T	M1	2.70	61.89	1.89
Raxter		♂	H	M1	2.59	83.85	4.22
Raxter		♂	R	M1	2.64	100.91	3.73
Raxter		♂	Fem	M1	2.26	63.93	3.22
Raxter		♂	T	M1	2.55	70.18	3.06
Ruff		♀	H	M1	3.38	54.60	3.94
Ruff		♀	R	M1	4.20	63.08	4.09
Ruff		♀	Fem	M1	2.69	43.56	2.92
Ruff		♂	H	M1	3.83	41.42	4.34
Ruff		♂	R	M1	4.85	47.46	4.53
Ruff		♂	Fem	M1	2.72	42.85	3.21
Trotter	Black	♀	H	M1	3.08	64.67	4.25
Trotter	Black	♀	R	M1	3.67	71.79	4.59
Trotter	Black	♀	U	M1	3.31	75.38	4.83
Trotter	Black	♀	Fem	M1	2.28	59.76	3.41
Trotter	Black	♀	Fib	M1	2.49	70.90	3.80
Trotter	Black	♂	H	M1	3.26	62.10	4.43
Trotter	Black	♂	R	M1	3.42	81.56	4.30
Trotter	Black	♂	U	M1	3.26	79.29	4.42
Trotter	Black	♂	Fem	M1	2.11	70.35	3.94
Trotter	Black	♂	Fib	M1	2.19	85.65	4.08
Trotter	White	♀	H	M1	3.36	57.97	4.45
Trotter	White	♀	R	M1	4.74	54.93	4.24
Trotter	White	♀	U	M1	4.27	57.76	4.30
Trotter	White	♀	Fem	M1	2.47	54.10	3.72
Trotter	White	♀	Fib	M1	2.93	59.61	3.57
Trotter	White	♂	H	M1	3.08	70.45	4.05
Trotter	White	♂	R	M1	3.78	79.01	4.320
Trotter	White	♂	U	M1	3.70	74.05	4.320
Trotter	White	♂	Fem	M1	2.38	61.41	3.270
Trotter	White	♂	Fib	M1	2.68	71.78	3.290
Trotter	Asian	♂	H	M1	2.68	83.19	4.250
Trotter	Asian	♂	R	M1	3.54	82.00	4.600
Trotter	Asian	♂	U	M1	3.48	77.45	4.660
Trotter	Asian	♂	Fem	M1	2.15	72.57	3.800
Trotter	Asian	♂	Fib	M1	2.40	80.56	3.24
Trotter	Mexican	♂	H	M1	2.92	73.94	4.24
Trotter	Mexican	♂	R	M1	3.55	80.71	4.04
Trotter	Mexican	♂	U	M1	3.56	74.56	4.05
Trotter	Mexican	♂	Fem	M1	2.44	58.67	2.99
Trotter	Mexican	♂	Fib	M1	2.50	75.44	3.52

The low number of individuals with a full set of long bone measurements (one female and four males) in the investigated osteological material necessitated outright rejection of the composite equations taking into consideration simultaneously two or more measurements when reconstructing stature [*Tables 9, 10A–B*], despite the fact that they are assumed to perform better at the task. At least three or even better four different bones from a single individual would have been needed in order to compare the stature verdict uniformity from formulae using pairs of measurements. Different bones in this case are understood as different elements of the skeleton; pairs of long bones differentiated only by the side of the body are thus considered as a single element.

Table 9. Available measurements of long bones; Means/ind. – number of measurements of long bones averaged by side for each individual; other columns give the number of individuals satisfying these criteria exactly, divided by sex

Means/ind.	♀	♂
0	607	666
1	162	138
2	51	56
3	27	29
4	13	12
5	6	5
6	1	4
Total	867	910

Disregarding the division into chronological phases when looking for a method that would be best suited to reconstructing stature of the skeletal population would facilitate direct comparisons between phases of the cemetery without having to discuss potential morphological differences between populations burying their dead within the established timeframe. This approach does not presume a morphological uniformity of the two phases that were discerned archaeologically, but it minimizes the impact of potential differences on the outcome of the comparisons. Assessing the biological distance between individuals buried in the two chronological phases was deemed unfeasible for lack of sufficient data on the skulls.

In effect, sex was adopted as the only segregating criterion. Methods exist that offer separate formulae enabling a reconstruction of stature based on measurements of the long bones of individuals of unknown sex (Ruff et al. 2012; Sjøvold 1990). In the Kom el-Dikka study, however, they could not be included for fear of disabling credible comparisons of the results with the results of other formulae in which sex was assumed as a distinctive criterion. Moreover, employing the same formulae for both sexes could also impede possible sexual-dimorphism analyses of stature.

3.3.5.3 *Bone measurement data for comparison*

The data set for the following considerations consisted of the maximum length of the longest skeleton limb bones (humerus, radius, ulna, femur, tibia, and fibula); this corresponds to the M1 measurement according to the classification by Rudolf Martin (Martin and Saller 1959: 532–542, 561–577) [see *Table 8*]. This choice, while retaining a strong link to the earliest anthropological analyses performed on Kom el-Dikka, made it impossible to base the reconstruction on, for example, the physiological length of the femur (M2)[12] and the true maximum length of the tibia (M1a), which unlike the maximum length, also takes into consideration the intercondylar eminence of the proximal end of the bone (Martin and Saller 1959: 572; Raxter et al. 2008: 149). Taking the M2 measurement of the femur and the M1a of the tibia could have been of significance for the sake of making comparisons with the estimations performed on the European series (Ruff et al. 2012) where the tibia M1 measurement was used for reconstructions by the anatomical method, but the M1a measurement alone was applied in the linear regression equations. The choice of different bone length measurements would have potentially been of importance also for further analyses had the Raxter method proved to be the most consistent for stature reconstruction in the case of Kom el-Dikka. Using composite formulae for the bones of the lower limbs in this case would be unfeasible as the pairs Fem(M1)+T(M1a) and Fem(M2)+T(M1) chosen by Raxter et al. for their estimations basically excluded the use of their formulae for the Kom el-Dikka material.

The Trotter and Glesser formulae developed for tibiae had to be excluded from the current considerations for a different reason, namely, that, as demonstrated by Jantz, Hunt, and Meadows (1994: 528), they apparently failed to take into account the medial malleous, overstating in effect the reconstructed stature calculated from the length of these bones.

Searching for the most consistent stature reconstruction method, it was also decided to exclude from the set taken into account all measurements that were burdened with additional uncertainty resulting from pathological changes, poor state of preservation or the effects of post-depositional factors (marked with asterisks [*], [**], [***] in the Catalog of burials B.1 in Appendix B). This was done in order not to introduce additional sources of error at the stage of method selection.

3.3.5.4 *Comparing formulae*

The first step was to average the measurements by body side in order to minimize the lateralization effect on the results. Not all authors of the stature reconstruction methods used here addressed the problem in a similar way. Pearson recommended adding Rollet's corrections, which resulted specifically from lateralization, to the length of the left-side bones (Pearson 1899: 197). However, according to Pearson, the error resulting from lateralization would be "hardly sensible except in the case of the humerus and radius", and should not affect the verdict significantly even if left uncompensated. Trotter and Gleser reached similar conclusions, although unlike Pearson they based their calculations on averaged measurements in their first study (1952: 512) and bones from both sides separately in the second (1958: 81). The approach to this issue was not discussed for the skeletons from Egypt (Raxter et al. 2008), but the authors of this method adopted stature reconstructed with Georges Fully's anatomical method as a reference (Raxter et al. 2008: 148), including a recommendation to average measurements by sides (Raxter et al. 2006: 376). Hence, it is only justified to assume that they did the same also in the case of measurements used later to formulate linear regression equations. The method based on European material adopted a mixed

[12] The M2 measurement is relatively difficult to take in the field, because it requires a wide osteometric board, and proper positioning of the femur depends heavily on good preservation of the distal end of the bone, which is rarely the case.

strategy, averaging the upper limb bone measurements, but using only the best preserved bones in the case of the lower limbs or, preservation of the bones permitting, the lengths from both sides of the skeleton on equal terms (Ruff et al. 2012: 604).

The second step, after averaging the measurement data, was to calculate stature using all the formulae available for a given bone element, but only for the elements with formulae provided by all the methods. Thus, equations for reconstructing stature using the length of single femur, humerus and radius bones were considered. Stature was calculated independently for each of the three bones (if available) in the case of every individual. The actual comparison of consistency took place only after this step was made.

Pairs of different long bones of separate individuals were a natural choice for these comparisons in a situation where the number of available measurements was expectedly low [***Tables 10A–B***]. The third step thus comprised calculation of the differences in stature for each pair of results obtained for bones belonging to a single individual, again separately for each of the methods. The procedure was repeated for every individual in the set. This way, for every individual in a sample with all bones preserved intact, a set of exactly three differences was calculated. The average differences were presented in tabular form.

Table 10. Number of individuals with long bone measurements averaged by side, divided by sex: A – pairs; B – sets of three

A

	♀	♂
humerus-radius	26	28
humerus-ulna	19	22
humerus-femur	17	26
humerus-tibia	21	14
humerus-fibula	16	12
radius-ulna	38	43
radius-femur	15	21
radius-tibia	19	19
radius-fibula	17	14
ulna-femur	13	21
ulna-tibia	18	17
ulna-fibula	15	15
femur-tibia	19	25
femur-fibula	11	21
tibia-fibula	21	27
Total	**285**	**325**

B

	♀	♂
humerus-radius-ulna	13	17
humerus-radius-femur	6	15
humerus-radius-tibia	9	8
humerus-radius-fibula	9	8
humerus-ulna-femur	7	14
humerus-ulna-tibia	8	8
humerus-ulna-fibula	5	7
humerus-femur-tibia	8	11
humerus-femur-fibula	4	9
humerus-tibia-fibula	9	7
radius-ulna-femur	9	14
radius-ulna-tibia	12	9
radius-ulna-fibula	11	11
radius-femur-tibia	8	9
radius-femur-fibula	5	9
radius-tibia-fibula	10	7
ulna-femur-tibia	8	11
ulna-femur-fibula	5	10
ulna-tibia-fibula	6	9
femur-tibia-fibula	7	14
Total	**159**	**207**

The consistency of respective methods was tested in the fourth step by examining the simple difference (Δ) between values obtained for different bone elements. The implication is that the mean difference for a given pair of bones should be closest to zero in the case of the most consistent method. Averages of differences were chosen for comparison instead of their variability, because it reduced to a minimum the impact of the varied availability of different parts of the skeleton on the results. Moreover, average stature is usually the choice value for intra- and inter-population comparisons.

A positive or negative average of this kind indicates only the direction of the observed differences, hence the growing sequence of absolute values reflecting averaged difference in the tabular presentation. If the average differed from zero, the expected value, statistical significance of its departure from zero was explored with the Wilcoxon signed rank test with continuity correction for one sample. The choice of a non-parametric test was dictated by the problematic nature of obtaining a credible normal distribution check in case of relatively small samples.

To test it even deeper, the statistical significance of the difference between mean differences between stature estimations for bone pairs was evaluated in the fifth step, for each of the combination of methods taken two at a time without repetition. As the stature estimations obtained using different methods were based on the same measurements, repeated measures design post-tests were used to take into account data pairing, while reducing the probability of a type I error for multiple comparisons. A `rmmcp()`, an R language implementation of a robust[13] test by Wilcox (Mair and Wilcox 2019), was employed with standard 20% trimming of the mean, to improve control over the type I error (Wilcox and Keselman 2003: 264). It was used without performing a prior ANOVA test, because the question lies in the differences between particular methods.[14] The obtained $\hat{\Psi}$ results, confidence intervals and critical values were tabularized for each combination of methods, taken two at a time without repetition, separately for each sex, taking into account the differences between Fem, H and R bones [***Tables 12A–C; 13A–C***]. They were arranged according to the absolute mean deviation from zero, taking into account first the mean *delta* reached by the first method in the pair and then the second, progressively, top down; significant differences were marked with an asterisk. The confidence level was set at 95%.

3.3.5.5 *Results of the comparison*

For females, the Ruff method yielded the lowest absolute mean difference ($\overline{\Delta}$) of stature calculated for the humerus–radius and humerus–femur pairs of bones [***Table 11A***]. For the radius–femur pair, the Trotter (b) method proved the best, displacing the Ruff method to third in rank. However, the results of the two-tailed one-sample Wilcoxon signed rank test with correction for continuity and with Benjamini–Hochberg's correction of p for multiple comparisons showed that there is no significant departure of the *delta* from zero for the R-Fem pairs in the first three methods. Moreover, the null hypothesis (H_0: $\bar{x}_1 = \bar{x}_2$) with a confidence level of 95% was not rejected for any method in the H-Fem group. It means that there is apparently no significant

[13] The robust test was used because, as indicated previously, a credible normal distribution check in the case of relatively small samples is problematic.

[14] Using post-hoc tests in multiple comparisons without first testing the significance for the whole group is established practice (Howell 2012: 372–373; Zar 2010: 226).

difference between zero and the mean difference after subtracting stature estimations calculated with any single method for the same individuals and using successively humerus and femur measurements in the appropriate equations. For the H–R pair, the null hypothesis was rejected in every case, Ruff included, questioning the significance of the superior position of this method in the group. For the R-Fem pair, which placed in the middle of the stake of significant test result counts, only the last two methods in the ranking had a mean difference significantly different from zero.

In the case of males, the Trotter (a) equation was first for all three bone pairs [*Table 11B*]. The null hypotheses were rejected for the three last values for the H-R pair, meaning that there were no statistically significant departures of mean *deltas* from zero for the first four methods in the ranking. The same was true for the H-Fem pair, and for R-Fem the null hypothesis was rejected only for the last method.

Testing the difference between mean differences of stature estimations (see step five above) demonstrated that the Trotter (b) method, which had given the best results for the R-Fem pair for females, stood out distinctly from the H-Fem formulae for females in terms of uniformity of estimations [*Table 12B*]; for this the previous tests had not been decisive [see *Table 11A*]. The absolute mean difference calculated for this method proved significantly higher than those for the next two counting from the end of the stake. At the same time, however, the top-ranking method did not turn out to have statistically significant superiority over the remaining ones. The analysis of pairwise differences between methods confirmed also that the Ruff method, which had given the best results for the H-R and H-Fem pairs, performed better in terms of uniformity of stature estimation for the H-R pairs [see *Table 12A*] compared to the Pearson and Trotter (w) formulae, which had placed second and last in the delta ranking [*Table 11A*]. The test results for R-Fem did not introduce any new information [*Table 12C*]. One should note the relatively small size of H-Fem and R-Fem samples, totaling 17 and 15 individuals respectively.

For males, the results were again much more informative than for females. For H-R [*Table 13A*], the absolute mean difference from the first listed method, Trotter (a), was significantly less than the absolute mean difference from the fourth (Raxter), this being tantamount to much greater consistency of the first of the two methods in the case of the sample studied. The same was observed for the H-Fem pair [*Table 13B*]. The fourth method in the *delta* ranking, Trotter (w), gave significantly less consistent results than Trotter (a). For the results for the R-Fem pair [*Table 13C*], the mean *delta* calculated from the first listed Trotter (a) is significantly smaller than most results in this group. Only Trotter (m) and Raxter did not prove significantly different. In the end, Trotter (a) and Trotter (m) proved to be almost equally consistent for males, even though for each examined bone pair, the first typically had a lower mean difference, lower median and lower standard deviation [*Table 11B*]. Assuming the consistency of stature estimation results for different parts of the skeleton as the chief criterion, the Trotter (a) method proved to be the best choice for males.

3.3.5.6 *Additional considerations*

The capacity to reconstruct stature for potentially the largest number of individuals in the analyzed set was the second criterion to be considered, apart from estimation consistency, particularly in the context of the severely damaged osteological material from the Lower Necropolis permitting very few stature estimations based on just three bones: humerus, femur and radius. The Raxter

Table 11. Statistical values for differences in estimated stature calculated using selected methods for two-element combinations without repetition of the humerus (H), radius (R), and femur (Fem) of: A – females; B – males; n – number of individuals with a particular pair of bones available; $\bar{\Delta}$ – mean difference in stature estimation; s – standard deviation; Me – median; Δ_{min} – the lowest difference calculated; Δ_{max} – the highest difference calculated; V – statistics of two-tailed one-sample Wilcoxon signed rank test with correction for continuity; p – p value; p_{adj} – p value with Benjamini–Hochberg's correction for multiple comparisons

A

Pair	Method	n	$\bar{\Delta}$	s	Me	Δ_{min}	Δ_{max}	V	p	p_{adj}
H–R	Ruff	26	–1.66	3.56	–1.49	–12.24	4.65	89	0.0300	0.0289
	Pearson		–2.42	2.87	–2.26	–10.80	2.65	38	0.0000	0.0009
	Raxter		2.46	2.92	2.28	–3.44	9.14	312	0.0000	0.0009
	Trotter (b)		2.62	3.19	2.82	–6.55	8.22	314	0.0000	0.0009
	Trotter (w)		–2.87	3.81	–2.76	–15.04	3.95	43	0.0000	0.0010
H–Fem	Ruff	17	–0.16	4.64	–0.64	–10.64	10.42	61	0.4900	0.4874
	Pearson		–0.27	3.67	–0.68	–7.93	8.66	56	0.3500	0.4874
	Raxter		0.85	3.94	0.50	–8.24	9.58	94	0.4300	0.4874
	Trotter (w)		1.19	4.51	0.71	–8.50	11.97	89	0.2900	0.4874
	Trotter (b)		1.80	4.14	1.31	–7.14	11.66	120	0.0400	0.1977
R–Fem	Trotter (b)	15	–0.32	3.83	0.17	–5.68	8.23	56	0.8500	0.8469
	Raxter		–1.59	4.44	–1.22	–8.93	6.48	39	0.2500	0.3155
	Ruff		1.99	4.54	2.84	–4.52	12.01	85	0.1700	0.2814
	Pearson		2.68	3.23	2.61	–1.76	10.10	109	0.0000	0.0084
	Trotter (w)		4.87	4.07	4.25	–0.77	14.56	117	0.0000	0.0015

B

Pair	Method	n	$\bar{\Delta}$	s	Me	Δ_{min}	Δ_{max}	V	p	p_{adj}
H–R	Trotter (a)	28	0.24	3.23	0.30	–7.08	7.51	226	0.6100	0.7098
	Trotter (m)		–0.26	3.52	–0.51	–8.05	8.09	187	0.7200	0.7241
	Trotter (b)		1.18	4.10	0.88	–7.19	11.26	261	0.1900	0.2666
	Raxter		1.34	3.30	1.06	–5.27	9.47	294	0.0400	0.0688
	Ruff		–2.26	4.60	–2.26	–12.59	8.42	97	0.0200	0.0380
	Trotter (w)		–2.56	3.71	–2.76	–10.80	6.20	64	0.0000	0.0056
	Pearson		–2.74	3.54	–3.04	–10.31	5.88	56	0.0000	0.0056
H–Fem	Trotter (a)	26	0.16	3.00	–0.49	–5.62	7.19	180	0.9200	0.9205
	Ruff		–0.27	4.04	–0.83	–8.71	9.22	160	0.7100	0.8258
	Trotter (m)		–0.58	3.39	–1.19	–6.83	7.24	131	0.2700	0.3762
	Trotter (w)		1.17	3.36	0.47	–5.52	9.11	234	0.1400	0.2462
	Raxter		1.75	3.13	1.24	–3.76	8.84	272	0.0100	0.0302
	Pearson		–1.78	3.04	–1.78	–8.24	5.11	74	0.0100	0.0302
	Trotter (b)		2.12	3.43	2.12	–5.17	9.86	282	0.0100	0.0302
R–Fem	Trotter (a)	21	0.02	3.13	–0.19	–7.00	7.83	116	1.0000	1.0000
	Trotter (m)		–0.13	3.65	–0.56	–8.44	9.52	113	0.9500	1.0000
	Trotter (b)		0.65	3.08	0.41	–6.29	8.40	148	0.2700	0.4253
	Raxter		0.68	3.72	0.78	–7.47	10.68	146	0.3000	0.4253
	Pearson		0.71	2.74	0.62	–5.31	7.24	153	0.2000	0.4253
	Ruff		1.84	3.97	1.77	–6.78	11.09	171	0.0500	0.1914
	Trotter (w)		3.78	3.48	3.47	–4.10	12.65	215	0.0000	0.0011

Table 12A. Wilcox post-hoc test statistics ($\hat{\Psi}$), confidence interval (CI_{lower} and CI_{upper}), p values and p critical values ($p_{critical}$), showing the pairwise comparison of stature estimation methods using the mean differences ($\bar{\Delta}$) between estimations produced by long bone H-R pairs for female individuals (n=26). Significant test results marked with an asterisk [*]

$\bar{\Delta}$		$\bar{\Delta}$	$\hat{\Psi}$	CI_{lower}	CI_{upper}	p	$p_{critical}$
Ruff	vs.	Pearson	–0.8167	–1.2737	–0.3596	0.000031	0.0057*
Ruff	vs.	Raxter	–0.8921	–5.0778	3.2937	0.4944	0.0102
Ruff	vs.	Trotter (b)	–1.3454	–5.6853	2.9944	0.3245	0.0085
Ruff	vs.	Trotter (w)	–1.1044	–1.5399	–0.6689	5.2E-07	0.0051*
Pearson	vs.	Raxter	–0.0580	–3.8662	3.7503	0.9608	0.0500
Pearson	vs.	Trotter (b)	–0.5266	–4.4066	3.3535	0.6620	0.0127
Pearson	vs.	Trotter (w)	–0.2583	–0.8752	0.3587	0.1891	0.0073
Raxter	vs.	Trotter (b)	–0.3662	–1.1512	0.4188	0.1461	0.0064
Raxter	vs.	Trotter (w)	–0.1260	–4.1828	3.9307	0.9200	0.0250
Trotter (b)	vs.	Trotter (w)	0.2999	–4.2942	4.8941	0.8330	0.0169

Table 12B. Wilcox post-hoc test statistics ($\hat{\Psi}$), confidence interval (CI_{lower} and CI_{upper}), p values and p critical values ($p_{critical}$), showing the pairwise comparison of stature estimation methods using the mean differences ($\bar{\Delta}$) between estimations produced by long bone H-Fem pairs for female individuals (n=17). Significant test results marked with an asterisk [*]

$\bar{\Delta}$		$\bar{\Delta}$	$\hat{\Psi}$	CI_{lower}	CI_{upper}	p	$p_{critical}$
Ruff	vs.	Pearson	–0.1323	–0.918	0.6534	0.5599	0.0073
Ruff	vs.	Raxter	0.2257	–3.9183	4.3697	0.8493	0.0169
Ruff	vs.	Trotter (w)	0.0713	–4.59	4.7326	0.9574	0.0500
Ruff	vs.	Trotter (b)	–0.5906	–5.0354	3.8543	0.6444	0.0102
Pearson	vs.	Raxter	0.3295	–3.5187	4.1776	0.7654	0.0127
Pearson	vs.	Trotter (w)	0.1131	–4.0794	4.3055	0.9250	0.0250
Pearson	vs.	Trotter (b)	–0.5415	–4.5508	3.4678	0.6390	0.0085
Raxter	vs.	Trotter (w)	–0.248	–0.9525	0.4565	0.2361	0.0064
Raxter	vs.	Trotter (b)	–0.9086	–1.3598	–0.4574	0.000029	0.0057*
Trotter (w)	vs.	Trotter (b)	–0.6546	–0.8391	–0.4701	1.7E-07	0.0051*

Table 12C. Wilcox post-hoc test statistics ($\hat{\Psi}$), confidence interval (CI_{lower} and CI_{upper}), p values and p critical values ($p_{critical}$), showing the pairwise comparison of stature estimation methods using the mean differences ($\bar{\Delta}$) between estimations produced by long bone R-Fem pairs for female individuals (n=15). Significant test results marked with an asterisk [*]

$\bar{\Delta}$		$\bar{\Delta}$	$\hat{\Psi}$	CI_{lower}	CI_{upper}	p	$p_{critical}$
Trotter (b)	vs.	Raxter	–1.2315	–2.4279	–0.035	0.0043	0.0064*
Trotter (b)	vs.	Ruff	–1.8269	–9.7709	6.1171	0.4038	0.0169
Trotter (b)	vs.	Pearson	–2.3674	–9.206	4.4712	0.2212	0.0127
Trotter (b)	vs.	Trotter (w)	–4.3422	–12.2464	3.5619	0.0684	0.0073
Raxter	vs.	Ruff	–1.0389	–9.4543	7.3766	0.6488	0.0500
Raxter	vs.	Pearson	–1.5898	–8.5983	5.4187	0.4100	0.0250
Raxter	vs.	Trotter (w)	–3.5727	–11.2095	4.064	0.1107	0.0085
Ruff	vs.	Pearson	–0.5707	–2.0131	0.8718	0.1679	0.0102
Ruff	vs.	Trotter (w)	–2.746	–3.6275	–1.8645	2.2E-06	0.0051*
Pearson	vs.	Trotter (w)	–2.1206	–3.2164	–1.0248	0.000075	0.0057*

Table 13A. Wilcox post-hoc test statistics ($\hat{\Psi}$), confidence interval (CI_{lower} and CI_{upper}), p values and p critical values ($p_{critical}$), showing the pairwise comparison of stature estimation methods using the mean differences ($\bar{\Delta}$) between estimations produced by long bone H-R pairs for male individuals (n=28). Significant test results marked with an asterisk [*]

$\bar{\Delta}$		$\bar{\Delta}$	$\hat{\Psi}$	CI_{lower}	CI_{upper}	p	$p_{critical}$
Trotter (a)	vs.	Trotter (m)	0.0914	–4.7596	4.9424	0.9472	0.0500
Trotter (a)	vs.	Trotter (b)	–0.9437	–2.0447	0.1573	0.0071	0.0029
Trotter (a)	vs.	Raxter	–1.0963	–1.9683	–0.2243	0.0003	0.0028*
Trotter (a)	vs.	Ruff	–1.8841	–7.4705	3.7024	0.2457	0.0045
Trotter (a)	vs.	Trotter (w)	–2.2093	–7.1881	2.7695	0.1320	0.0042
Trotter (a)	vs.	Pearson	–2.4044	–7.3016	2.4928	0.0981	0.0038
Trotter (m)	vs.	Trotter (b)	–0.9758	–6.4582	4.5067	0.5341	0.0127
Trotter (m)	vs.	Raxter	–1.1258	–6.0588	3.8072	0.4271	0.0102
Trotter (m)	vs.	Ruff	–1.9581	–2.7544	–1.1618	1E-07	0.0026*
Trotter (m)	vs.	Trotter (w)	–2.2974	–2.4392	–2.1557	0.0000	0.0025*
Trotter (m)	vs.	Pearson	–2.4877	–2.7603	–2.2151	0.0000	0.0024*
Trotter (b)	vs.	Raxter	–0.1500	–0.7327	0.4327	0.3715	0.0064
Trotter (b)	vs.	Ruff	–0.9856	–7.1832	5.2120	0.5781	0.0169
Trotter (b)	vs.	Trotter (w)	–1.3224	–6.8748	4.2300	0.4076	0.0073
Trotter (b)	vs.	Pearson	–1.5689	–7.2533	4.1154	0.3389	0.0057
Raxter	vs.	Ruff	–0.8356	–6.4505	4.7793	0.6026	0.0250
Raxter	vs.	Trotter (w)	–1.1724	–6.1742	3.8295	0.4149	0.0085
Raxter	vs.	Pearson	–1.4273	–6.5160	3.6613	0.3313	0.0051
Ruff	vs.	Trotter (w)	–0.3393	–0.9953	0.3166	0.0826	0.0036
Ruff	vs.	Pearson	–0.5802	–1.5777	0.4172	0.0536	0.0033
Trotter (w)	vs.	Pearson	–0.2077	–0.5629	0.1474	0.0524	0.0031

Table 13B. Wilcox post-hoc test statistics ($\hat{\Psi}$), confidence interval (CI_{lower} and CI_{upper}), p values and p critical values ($p_{critical}$), showing the pairwise comparison of stature estimation methods using the mean differences ($\bar{\Delta}$) between estimations produced by long bone H-Fem pairs for male individuals (n=26). Significant test results marked with an asterisk [*]

$\bar{\Delta}$		$\bar{\Delta}$	$\hat{\Psi}$	CI_{lower}	CI_{upper}	p	$p_{critical}$
Trotter (a)	vs.	Ruff	–0.6111	–6.3265	5.1043	0.7020	0.0102
Trotter (a)	vs.	Trotter (m)	–0.9506	–5.9717	4.0704	0.5004	0.0051
Trotter (a)	vs.	Trotter (w)	–0.9889	–1.3048	–0.6729	8.5E-09	0.0025*
Trotter (a)	vs.	Raxter	–1.6523	–1.9775	–1.3272	9.5E-12	0.0024*
Trotter (a)	vs.	Pearson	–2.0150	–7.0779	3.0479	0.1672	0.0036
Trotter (a)	vs.	Trotter (b)	–1.8067	–2.6702	–0.9433	0.0000015	0.0026*
Ruff	vs.	Trotter (m)	–0.1691	–0.9714	0.6331	0.4539	0.0042
Ruff	vs.	Trotter (w)	–0.387	–6.4663	5.6923	0.8195	0.0169
Ruff	vs.	Raxter	–0.9477	–6.6014	4.706	0.5501	0.0064
Ruff	vs.	Pearson	–1.3949	–2.2573	–0.5326	0.000029	0.0028*
Ruff	vs.	Trotter (b)	–1.3959	–7.9224	5.1306	0.4474	0.0038
Trotter (m)	vs.	Trotter (w)	–0.0475	–5.3801	5.2851	0.9745	0.0250
Trotter (m)	vs.	Raxter	–0.5705	–5.5932	4.4521	0.6845	0.0085
Trotter (m)	vs.	Pearson	–1.3130	–2.4091	–0.2168	0.0005	0.0031*
Trotter (m)	vs.	Trotter (b)	–1.0753	–6.5328	4.3822	0.4834	0.0045
Trotter (w)	vs.	Raxter	–0.6622	–1.1228	–0.2016	0.000099	0.0029*
Trotter (w)	vs.	Pearson	–1.0101	–6.5196	4.4995	0.5138	0.0057
Trotter (w)	vs.	Trotter (b)	–0.8096	–1.5802	–0.0389	0.0016	0.0033*
Raxter	vs.	Pearson	–0.4562	–5.2742	4.3618	0.7346	0.0127
Raxter	vs.	Trotter (b)	–0.1425	–1.3430	1.0579	0.6712	0.0073
Pearson	vs.	Trotter (b)	–0.0027	–5.4041	5.3987	0.9986	0.0500

Table 13C. Wilcox post-hoc test statistics ($\hat{\Psi}$), confidence interval (CI_{lower} and CI_{upper}), p values and p critical values ($p_{critical}$), showing the pairwise comparison of stature estimation methods using the mean differences ($\bar{\Delta}$) between estimations produced by long bone R-Fem pairs for male individuals (n=21). Significant test results marked with an asterisk [*]

$\bar{\Delta}$		$\bar{\Delta}$	$\hat{\Psi}$	CI_{lower}	CI_{upper}	p	$p_{critical}$
Trotter (a)	vs.	Trotter (m)	–0.0451	–4.9705	4.8802	0.9726	0.0500
Trotter (a)	vs.	Trotter (b)	–0.6203	–0.6938	–0.5468	4.8E-13	0.0026*
Trotter (a)	vs.	Raxter	–0.4633	–1.2963	0.3698	0.0544	0.0057
Trotter (a)	vs.	Pearson	–0.6708	–0.9834	–0.3582	2.8E-06	0.0033*
Trotter (a)	vs.	Ruff	–1.8344	–2.7624	–0.9064	6.5E-06	0.0036*
Trotter (a)	vs.	Trotter (w)	–3.7672	–4.0276	–3.5069	8.9E-16	0.0024*
Trotter (m)	vs.	Trotter (b)	–0.5741	–5.4329	4.2847	0.6587	0.0169
Trotter (m)	vs.	Raxter	–0.5655	–5.8192	4.6882	0.6872	0.0250
Trotter (m)	vs.	Pearson	–0.6520	–5.3630	4.0590	0.6054	0.0127
Trotter (m)	vs.	Ruff	–1.8442	–7.2253	3.5370	0.2135	0.0064
Trotter (m)	vs.	Trotter (w)	–3.7033	–8.8387	1.4320	0.0171	0.0051
Trotter (b)	vs.	Raxter	0.1495	–0.6034	0.9024	0.4612	0.0102
Trotter (b)	vs.	Pearson	–0.0696	–0.3494	0.2102	0.3590	0.0085
Trotter (b)	vs.	Ruff	–1.2123	–2.2160	–0.2087	0.0006	0.0045*
Trotter (b)	vs.	Trotter (w)	–3.1303	–3.4319	–2.8287	4.1E-14	0.0025*
Raxter	vs.	Pearson	–0.2429	–1.0606	0.5747	0.2770	0.0073
Raxter	vs.	Ruff	–1.3247	–2.2944	–0.3551	0.0002	0.0038*
Raxter	vs.	Trotter (w)	–3.2319	–4.1197	–2.3441	8.9E-09	0.0029*
Pearson	vs.	Ruff	–1.1918	–2.1746	–0.2091	0.0006	0.0042*
Pearson	vs.	Trotter (w)	–3.0976	–3.6677	–2.5274	8.7E-11	0.0028*
Ruff	vs.	Trotter (w)	–1.9062	–2.5845	–1.2278	1.6E-07	0.0031*

and Pearson methods would have allowed tibiae to be included in the study, while any of the methods from the Trotter group would have excluded them, but would have included the fibulae and ulnae instead.

For the sake of comparison, the percentage gain in the number of potential stature estimations for the four elements FemHRT was calculated in comparison to the five FemHRFibU [*Table 14*]. This was performed separately for measurements burdened with various levels of uncertainty. The lowest gain in favor of a set with fibulae and ulnae (5.56%) was noted in the case of measurements of the female bones from the Lower Necropolis with the uncertainty threshold set to 2. It was followed by male bones from the Upper Necropolis (6.39% and 9.36%), with uncertainty levels 3 and 2 respectively. The gains in the remaining cases were no lower than 10% and as high as 45% for males from the Lower Necropolis (uncertainty level 3). In the case of measurements from the Upper Necropolis not burdened with additional uncertainty, the gain in favor of the variant with fibulae and ulnae instead of tibiae amounted to 10% for males and 13.59% for females, respectively 25% and 12.5% for the Lower Necropolis.

Taking into consideration the number of potential estimations only, one of the Trotter methods proved to be better than the other three, that is, Pearson, Raxter and Ruff, with Ruff placing last in the potentiality ranking. Moreover, the observed difference in the case of Kom el-Dikka did not outweigh the benefits of selecting the most consistent method for females. For males, there were no such doubts as one of the Trotter methods proved the most consistent (see discussion below).

Table 14. Number of measurements allowing stature estimation of individuals classified by necropolis phase, based on three different sets of bones (FemHR, FemHRT, and FemHRFibU), and taking sex into consideration, calculated separately for different levels of uncertainty of measurements allowed; *n* – number of individuals with measurements allowing estimation of stature; gain – difference in the number of potential estimations between methods capable of using the femur, humerus, radius, fibula, and ulna (FemHRFibU) and femur, humerus, radius, and tibia (FemHRT) bones

			Uncertainty (0)			Uncertainty (1)			Uncertainty (2)			Uncertainty (3)		
			♀	♂	**Σ**	♀	♂	**Σ**	♀	♂	**Σ**	♀	♂	**Σ**
Lower Necropolis	FemHR	*n*	14	14	28	14	15	29	16	15	31	17	18	35
	FemHRT	*n*	16	16	32	16	17	33	18	17	35	19	20	39
	gain	*n*	2	4	6	2	4	6	1	5	6	3	9	12
		%	12.50	25.00	18.75	12.50	23.53	18.18	5.56	29.41	17.14	15.79	45.00	30.77
	FemHRFibU	*n*	18	20	38	18	21	39	19	22	41	22	29	51
Upper Necropolis	FemHR	*n*	193	163	356	193	165	358	203	176	379	216	188	404
	FemHRT	*n*	206	190	396	208	192	400	215	203	418	232	219	451
	gain	*n*	28	19	47	26	20	46	30	19	49	26	14	40
		%	13.59	10.00	11.87	12.50	10.42	11.50	13.95	9.36	11.72	11.21	6.39	8.87
	FemHRFibU	*n*	234	209	443	234	212	446	245	222	467	258	233	491
Σ	FemHR	*n*	207	177	384	207	180	387	219	191	410	234	207	441
	FemHRT	*n*	222	206	428	224	209	433	233	220	453	252	240	492
	gain	*n*	30	23	53	28	24	52	31	25	56	29	24	53
		%	13.51	11.17	12.38	12.5	11.48	12.01	13.3	11.36	12.36	11.51	10.00	10.77
	FemHRFibU	*n*	252	229	481	252	233	485	264	245	509	281	264	545

3.3.5.7 *Ultimate choice of methods*

The results discussed above did not suggest one single method as the best choice for the present study. The most consistent Ruff method for females turned out unsuitable for the male group. The absolute mean difference with this method for males, which is statistically significantly higher for the H-R bone pair, was second to last in the R-Fem group (although the difference was not statistically significant). Summing it up, the values obtained using Ruff were very different from analogous values calculated using the Trotter (a) method, which performed best for males. Considering the choice of methods the other way around, the Trotter (a) method was developed for the East Asian male group and has no counterpart for estimating female stature. Therefore it is not possible to compare its consistency directly with the results for females. The same concerns the next method in the ranking for males, that is, Trotter (m). Therefore, taking into consideration the consistency of the equations, the choice would be to calculate female stature with the Ruff and male stature with the Trotter (a) formulae.

Consistency analyses for sets encompassing also other long bones measured, the tibia, fibula and ulna—had they been performed—would have in all probability not contradicted the conclusions reached here either.

The results for the most consistent methods show that the mean differences for bone pairs composed of T and elements of the FemHR set are generally more uniform for females with the Pearson and for males with the Raxter method [*Table 15A–B*]. Taking into consideration only these two methods (as only they provided appropriate fomulae for tibiae), these gave the same relative ranking with regard to the H-R, H-Fem and R-Fem differences [see *Tables 11A–B*]. If the M1 tibia measurements were deemed irreplaceable in future research, the dispersion of deltas would in all likelihood determine the choice of method.[15] For females, the mean differences for bone pairs composed of Fib and U, and either of these two combined with Fem, H, and R, indicated five times the superiority of Trotter (b) over all four Trotter methods (only these allowed fibula and ulna to be taken into account). Trotter (b) proved to be more consistent than Trotter (w), the latter topping the ranking only twice [*Table 16A*]. For males, the situation was not as evident [*Table 16B*]. The Trotter (b) method was listed first in three instances but was in this respect only slightly superior to the double winners Trotter (a) and Trotter (w), especially in view of the results for the combination of Fem, H, and R bones. One should also note the complete absence of Trotter (m) in this listing, additionally confirming the suitability of the Trotter (a) method, as determined above.

3.3.6 Application of selected stature reconstruction methods

Regression equations based on measurements of single bones, as required by the selected methods, that is, Ruff for women and Trotter (a) for men, are presented in tabular form [see *Table 8*]. Formulae using the lengths of more than one part of the skeleton, which were not useful in the method

[15] The set of Pearson formulae appears to have generally the lowest standard deviation of all the tested methods for calculating the differences for the Fem, H and R bones, although Trotter (a) seems to perform slightly better in this respect if only males are taken into account. The Pearson formulae also demonstrate the lowest values of the linear regression coefficient [see above, ***Table 8***] which is responsible for the inclination of the line on a graph; the lower it is, the greater the immunity of stature estimations to errors resulting from uncertainty of measurement data.

Table 15. Statistical values for differences in estimated stature, calculated using the method giving the lowest absolute value of the average for a two-element combination without repetition for the set of tibia (T), humerus (H), radius (R), and femur (Fem) bones where the tibia is one of the elements. Chart for: A – females; B – males; *n* – number of individuals with a particular pair of bones available; $\bar{\Delta}$ – mean difference in stature estimation; *s* – standard deviation; *Me* – median; Δ_{min} – the lowest difference calculated; Δ_{max} – the highest difference calculated; *V* – statistics of two-tailed one-sample Wilcoxon signed rank test with correction for continuity; *p* – *p* value

A

Pair	Method	*n*	$\bar{\Delta}$	*s*	*Me*	Δ_{min}	Δ_{max}	*V*	*p*
Fem–T	Raxter	19	–0.10	3.32	–1.37	–5.12	10.49	78	0.52
H–T	Pearson	21	–0.92	2.01	–0.34	–7.09	1.63	64	0.08
R–T	Pearson	19	0.16	2.22	0.50	–3.41	4.34	97	0.95

B

Pair	Method	*n*	$\bar{\Delta}$	*s*	*Me*	Δ_{min}	Δ_{max}	*V*	*p*
Fem–T	Raxter	25	–1.06	3.59	–0.72	–10.17	4.23	115	0.21
H–T	Raxter	14	1.56	4.25	2.98	–7.90	6.02	75	0.17
R–T	Raxter	19	–1.24	4.29	–0.57	–14.24	6.38	63	0.21

Table 16. Statistical values for differences in estimated stature, calculated using the method giving the lowest absolute value of the average for a two-element combination without repetition for the set of fibula (Fib), ulna (U), humerus (H), radius (R), and femur (Fem) bones where the fibula or ulna are one of the elements. Chart for: A – females; B – males; *n* – number of individuals with a particular pair of bones available; $\bar{\Delta}$ – mean difference in stature estimation; *s* – standard deviation; *Me* – median; Δ_{min} – the lowest difference calculated; Δ_{max} – the highest difference calculated; *V* – statistics of two-tailed one-sample Wilcoxon signed rank test with correction for continuity; *p* – *p* value

A

Pair	Method	*n*	$\bar{\Delta}$	*s*	*Me*	Δ_{min}	Δ_{max}	*V*	*p*
Fem–Fib	Trotter (b)	11	–0.3048	3.1192	–0.1870	–6.6610	4.8230	28	0.7002
U–Fem	Trotter (b)	13	1.6772	3.9603	2.7790	–6.0170	8.7145	65	0.1909
H–U	Trotter (b)	19	0.8294	4.4215	0.1835	–11.2590	7.1550	120	0.3321
H–Fib	Trotter (w)	16	–0.1287	3.3511	0.9290	–8.3240	3.8570	78	0.6322
R–U	Trotter (w)	38	0.2601	1.6029	0.5095	–4.1290	3.1340	459	0.2019
R–Fib	Trotter (b)	17	–0.6578	1.6985	–0.9060	–3.0430	3.8835	36	0.0569
U–Fib	Trotter (b)	15	2.1415	3.7202	1.4890	–2.5830	11.7590	95	0.0479

B

Pair	Method	*n*	$\bar{\Delta}$	*s*	*Me*	Δ_{min}	Δ_{max}	*V*	*p*
Fem–Fib	Trotter (b)	21	–0.1973	5.9224	–1.2520	–7.7290	23.3030	66.0	0.0885
U–Fem	Trotter (a)	21	0.1579	5.6057	0.5540	–17.3780	7.1245	140.0	0.4120
H–U	Trotter (a)	22	0.0589	4.9809	–0.7060	–7.6320	14.8860	110.0	0.6102
H–Fib	Trotter (w)	12	1.1975	8.6764	–0.1540	–9.6180	25.7480	39.0	1.0000
R–U	Trotter (w)	43	0.0643	3.1358	–0.2140	–4.8560	17.2960	404.5	0.4116
R–Fib	Trotter (b)	14	1.1300	6.4799	–0.5815	–6.0460	22.3490	49.0	0.8552
U–Fib	Trotter (b)	15	0.7388	3.2767	–0.1340	–5.5140	6.9990	64.0	0.8469

selection procedure and which are used in this study (see below, *§ 3.4.3*) to calculate the stature of male individuals, are presented in the form of equations [*Formula 7*] (Piontek 1996: 180). No such equations were available for females. In the stature analysis proper, all available measurements of long bone length were used, including those burdened with measurement uncertainty.

$$\begin{aligned} &1.22\,(Fem + Fib) + 70.24\,(\pm 3.18)\\ &1.68\,(H + U) + 71.18\,(\pm 4.14)\\ &1.67\,(H + R) + 74.83\,(\pm 4.16)\end{aligned} \qquad (7)$$

Where:

Fem	:	length of femur (in cm);
Fib	:	length of fibula (in cm);
H	:	length of humerus (in cm);
U	:	length of ulna (in cm);
R	:	length of radius (in cm);
± 0.00	:	standard error (uncertainty) of the estimate.

Stature was reconstructed using long bone measurements from adults only, within the limits allowed by the respective methods. For the sake of stature estimation, adulthood was assumed as the complete fusion of long bone shafts and epiphyses.

Measurements were first averaged by side, same as in the case of the method selection procedure. However, this was done only under the condition that both lengths in a pair of bones differing only by body side had the same maximum uncertainty of measurement (*MUM*). Otherwise, the length of the bone in the pair with a smaller error of measurement was considered as the average for the element in question. In cases where the condition of the skeletal remains allowed length measurements averaged by side of more than one element, estimations made on the basis of averages giving the lowest maximum uncertainty of stature estimation (*MUE*) were selected. In the next step, if there was more than one estimation burdened with the same *MUE*, the estimation with the lowest standard error of the estimate (*SEE*) was chosen (using *SEE* values provided by the authors of the methods used).

Giannecchini and Moggi-Cecchi (2008: 287) in their analysis of the series from Italy adopted a diametrically different strategy, averaging all the obtained estimations of an individual instead of selecting the one with the lowest *SEE* in order to avoid a non-random distribution of uncertainty. They achieved a reduction of the variation of the standard error of the estimate and not, as here, minimized uncertainty.

3.3.7 Sexual dimorphism of stature in assessing wellbeing

Considered from the point of view of sexual dimorphism, stature can be, again, useful in assessing the wellbeing of a population (Lorkiewicz and Smiszkiewicz-Skwarska 2003: 223), and indirectly, it can also help to track diachronic changes occurring in a population (Wiercińska 1983: 132). This is due to the relatively low dependence of stature on the genotype and the high ecosensitivity and varied reactivity of males and females (Frayer and Wolpoff 1985: 431–432; Wolański 2008:

125). In most cases research on the dimorphism of skeletal populations is based directly on a comparison of the length of long bones. The sum of the lengths (M1 measurements and possibly M2 for the femur; according to Martin and Saller 1959) of H, R, Fem and T is taken as the equivalent of stature (Lorkiewicz and Smiszkiewicz-Skwarska 2003: 219; Piontek 2003: 63; Wiercińska 1983: 121). In this study, however, reconstructed stature is used to assess dimorphism, this in view of the almost complete lack of sets of measurements for all four bones required [see *Table 14*].

A dimorphism scale for human stature was prepared by Napoleon Wolański based on studies of modern populations. To each of the percentage ranges distinguished, he assigned a wellbeing characteristic. Here, his formula for sexual dimorphism was applied to the means [*Formula 8*] and the results obtained were interpreted in accordance with the listed ranges (Wolański 2008: 126).

$$D_{♀♂} = \frac{\overline{h}_{♂} - \overline{h}_{♀}}{\overline{h}_{♀}} \times 100 \qquad (8)$$

Where:

$D_{♀♂}$: sexual dimorphism;
$\overline{h}_{♀}$: mean female stature;
$\overline{h}_{♂}$: mean male stature.

The assumption was that the application of modern patterns to skeletal populations may have cognitive value if the results are used only as a guide, supplementing or merely supporting the picture of the Kom el-Dikka population reconstructed from other sources.

3.3.8 Dentition

Regardless of its role in detailed analyses, like that in age-at-death estimation, dentition deserves a separate discussion because of the different structure and specific function of teeth in the human body. Teeth are a priceless source of additional information in view of their shape, state of preservation and changes due to internal and external factors both at the time of formation and later, when they are fully developed.

The extreme unevenness of odontological data from Kom el-Dikka, collected by the different researchers over the years (see the section on the material above), resulted in this part of the study being based exclusively on the author's own observations. Since 2005, the workflow has included an examination of each tooth and tooth socket separately. Retrospective individualization of the bulk of the general information in this respect, collected during the season in 2004, was not always possible.

Only permanent dentition was taken into consideration in the current study. Individual teeth were identified according to Jochen Viohl's formula from 1966, recommended since 1970 by the FDI World Dental Federation/Fédération Dentaire Internationale and adopted by the International Organization for Standardization (ISO) in 1995. Each tooth has a two-digit code, the first digit referring to one of four parts of the dentition in clockwise order (looking face to face), starting from 1 (upper right half of the maxilla), 2 (upper left half of the maxilla), 3 (lower left half of the mandibula), 4 (lower right half of the mandibula). The second digit (from 1 to 8) describes consecutive teeth in each quarter, in a growing sequence from the medial incisor to the third molar (Alt et al. 1998: 42, 44–45).

Assessment of the state of preservation of the tooth and socket is crucial for every analysis, adding credibility to observations by indicating what could and what could not be observed. The impact of diagenetic factors was noted, but also degree of formation of examined elements and, in part, changes due to pathological processes, such as closing of the tooth socket after tooth loss. Recording concerned: presence or absence of a tooth socket; presence or absence of a tooth; whether the tooth was in a socket or not; whether it was erupted or not; whether the tooth was mechanically damaged; and if so whether this had occurred during life or post mortem; loss of tooth during life and degree of obliteration of the alveolus; post mortem tooth loss; destruction of a tooth or of a tooth socket; and doubtful cases. Uncertainty of the state-of-preservation assessment of the tooth and tooth socket was noted separately. Observations entered in the database included also information on the dental wear, caries and enamel hypoplasia. The scope of collected data was subordinated to the selected method of analysis. The focus was on caries and enamel hypoplasia as carrying the greatest potential for tracking diachronic differences in living standards of the people buried in the cemetery. Characteristics like periapical changes or tartar were omitted, being considered as of much less significance for further reasoning, because both are closely related to factors reflected in dental caries, that is, oral hygiene and a carbohydrate-rich diet (although there could be a weak negative correlation between caries and tartar, see Hillson 1996: 260).

Enamel hypoplasia, which is the result of improper mineralization of the enamel, reflects physiological stress to the human organism during the period of tooth formation (Larsen 1997: 43–46), that is, the early years of an individual's life when external factors directly affecting unerupted teeth are largely negligible. Thus, the presence of enamel hypoplasia is not determined by the abrasive foods in the diet, possible deficiencies in the geometry of the chewing apparatus or even chemical and biological balance in the oral cavity. Macroscopic observation was the only available form of examination that could be taken into consideration in view of the specificity of the analyses conducted to date. The limitations imposed by this approach called for hypoplastic changes to be assessed on a general four-grade scale proposed by Michael Schultz (Steckel et al. 2006: 16) for defects described as LEH, linear enamel hypoplasia (Goodman and Martin 2002: 22–23). However, the very frequency of its presence in the sample could track potential differences of living conditions between populations (Goodman and Rose 1991: 282).

The mechanism of caries formation is also relatively well known (Caselitz 1998: 203–204). Nonetheless, due to the large number of factors influencing this process, the use of carious lesions in anthropological comparisons requires taking into account also intravital tooth loss and tooth crown wear. With a few exceptions, there is a negative correlation between caries and tooth wear (Lanfranco and Eggers 2012: 15–16). Therefore, these two characteristics should be considered in conjunction. In addition, since caries are in general age-correlated, one should check whether the percentages of individuals in different age-at-death brackets are similar in the groups studied (here in the Lower and Upper Necropolis) and to ensure that they are comparable with each other in order to address possible differences.

In the comparisons between phases, a simple frequency analysis was supplemented with a composite measure of caries. Thus, without going into the methodological controversies around the validity of using either of the approaches (Wasterlain, Hillson, and Cunha 2009: 68), both of them were used in the analysis to allow the broadest possible comparability of the results in future studies. From a purely utilitarian point of view, the advantage of a composite index over simple frequencies, especially in the case of poorly preserved skeletal material, is that it includes in the statistics also those individuals for whom there were no preserved teeth.

The I-CE index (index of caries *et extractio*) [*Formula 9*] was selected, taking into consideration teeth that were examined, those whose loss was intravital, and those lost post mortem (Caselitz 1998: 206; Saunders, De Vito, and Katzenberg 1997). Despite its relatively low complexity compared to formulae that take into account the different probability of decay in anterior and posterior teeth (Duyar and Erdal 2003: 59), this method offers the possibility of including several basic observations in a single numerical evaluation. The simplicity of such a result will allow it to be used in future research involving interpopulation comparisons. Such synthetic measures, as well as the usual frequency of caries and intravital tooth loss, do not take into account many significant differences (Lanfranco and Eggers 2010: 89; 2012: 21). Yet, easy application, which makes them resistant to errors, and facile understanding of the results places them in the forefront of routine odontological analysis.

$$I_{CE} = \frac{ct + il}{tp}$$
$$tp = t + pl + il \qquad (9)$$

Where:

I_{CE}	:	index I-CE (index of caries *et extractio*);
ct	:	number of teeth with caries;
il	:	number of teeth lost intravitally;
tp	:	number of all tooth positions;
pl	:	number of teeth lost post mortem;
t	:	number of teeth.

Because of the theoretical possibility that not fully erupted teeth could have still been concealed under soft tissue at the time of death, as Peter Lingström and Hélène Borrman (1999: 397) point out, only fully erupted permanent teeth were considered in calculations included in this study. They had to be identified in the context of a specific skeleton[16] as well as a specific tooth socket. Very damaged teeth were also included in the overall number of teeth when at least one root was preserved in the alveolus, and the same was done for broken teeth without signs of occlusion. Those lost post mortem were identified by an empty alveolus without any trace of bone remodeling. Where traces of remodeling were noted, the tooth was counted as an intravital loss, unless there

[16] Whenever a skull or a fragment of the skull with teeth could not be convincingly assigned to a postcranial skeleton, a "temporary" individual was created instead, but only for the purposes of odontological analysis and calculations. In such cases there is no corresponding number in the appropriate column of the catalog in the appendix.

was a tooth that could be associated beyond doubt with a particular tooth position despite the identified bone changes.

Beside simple comparison of frequencies of individuals with caries and analysis of carious lesions taking tooth positions into account,[17] the condition was considered also from the point of view of the severity of the observed changes (Caselitz 1998: 218), using the scale proposed by Peter Caselitz (1998: Table 3). This was done to some extent to counter reservations concerning the use of a simple incidence of carious lesions without taking into account other characteristics of this condition.

Assessment of crown wear, a condition used here as an auxiliary element in caries analysis, called for the use of B. Holly Smith's scales (1984: 46), selectively reproduced in popular osteological reference manuals (Buikstra and Ubelaker 1994: 52; Steckel et al. 2006: 19). Knowing that the degree of wear for grades 6, 7, and 8 is strongly dependent on the uniformity of wear, a stated grade 7 of crown wear (for which assessment it was essential first to determine the completeness of the crown edge) was not considered as actually evaluating degree of wear because of the effect of potential irregularities of the chewing apparatus. It was thus included in the grade 6 assessment, whereas Smith's grade 8, signifying a complete wearing down of the crown, assumed the value of 7. This modification will not affect a potential reassessment of degrees of wear in the context of the age-at-death because degrees of wear higher than 6 are in any case useless for age determination using scales introduced by Lovejoy (1985: 49–50), which are widely applied in anthropological studies (Piontek 1996: 172; White 2000: 346). Moreover, it will not affect the usefulness of the scale when evaluating the state of preservation of the crown prior to an assessment of tooth caries or enamel hypoplasia.

In view of the identified difference between the sexes with regard to the chemistry inside the oral cavity and use of the chewing apparatus (Lanfranco and Eggers 2012: 17–18; Lukacs and Largaespada 2006), both caries and enamel hypoplasia were considered separately for men and women, and for both groups combined. The low count of individuals, particularly in the case of the Lower Necropolis, resulted in the differences, with sex taken into account, being studied only in summary statements, not taking into consideration the position of a tooth in a socket.

Adults and children were considered separately as far as possible, owing to the big differences in how caries and crown wear are manifested. The age limit between the two groups was assumed at 20 years and all the individuals for which half or the greater part of the age-at-death range resulting from a bioarchaeological evaluation was above this value were considered as adults. The remainder were considered as children.

3.3.9 *Cribra orbitalia*

The second most widely used determinant of physiological stress in the early stages of human life, after enamel hypoplasia, is porotic hyperostosis of the orbital roof (Lorkiewicz 2012: 131). It is the only skeletal pathology (apart from the dentition and dental alveolus observations described above, comprising caries and enamel hypoplasia) that was taken into account in this study of the changes in the wellbeing of the Islamic population of early Alexandria over the centuries.

[17] Due to the small sample from the Lower Necropolis in particular, it was decided to present the teeth from the maxilla and mandibula together, and to refrain from distinguishing them by sides.

The role of iron deficiency, widely accepted as a general cause of this change (Goodman and Martin 2002: 27–29; Larsen 1997: 29–33; Lewis 2007: 112–113; Roberts and Manchester 2005: 229–233) has been challenged convincingly in favor of a diagnosis assuming hemolytic, congenital, or megaloblastic anemia associated with nutritional deficiencies and B_{12} vitamin assimilation disorders (Walker et al. 2009). The debate continues (Klaus 2017: 98–101; McIlvaine 2015; Oxenham and Cavill 2010; Rivera and Mirazón Lahr 2017; Smith-Guzmán 2015: 1; Wapler, Crubezy, and Schultz 2004), but the picture that emerges from it argues for a heterogeneous, multifactorial, both genetic and environmental, etiology of such changes.

In the present study, *cribra orbitalia* were observed for each eye socket separately and assessed on a four-grade scale (0–3) (Steckel et al. 2006: 13). Moreover, the uncertainty of these observations, resulting from the frequently poor state of preservation of the orbital roof, was evaluated on a three-grade scale.

This element was investigated by a simple comparison of frequencies of individuals manifesting it between the groups distinguished by sex, age and chronological phase of the cemetery. The age-at-death classification of the individuals buried in the cemetery is presented in *§ 3.3.4* and adulthood was set at 20 years, as for the odontological analysis. If half or the greater part of the range of an individual's biological age at the time of death, as determined by the analyses, fell above the upper limit specified for a particular age group, the individual was classified in the higher category; otherwise, (s)he remained in the age group considered. The lower limit was set by the upper limit of the lower category. The data concerning individuals from the lowest category, zero and below, were not taken into account.

3.3.10 Representativeness of the sample

To make things simple, it is assumed that the sample of human skeletal remains from archaeological contexts is random. It is so on the premise that a series of appropriate size should guarantee the representativeness of the sample for a studied skeletal population, and this, as was believed, may be transposed directly onto the living population, of which the skeletal population is a representative subset. The beginnings of this approach in Western science go back to the 1960s and 1970s (Shennan 1997: 361–362), especially to processual archaeology with its belief that burials can be studied for a direct reconstruction of living societies (Lewartowski 2001: 136–137; Martin, Harrod, and Pérez 2013: 131–132). In spite of numerous doubts, the conviction about the random nature of the archaeological sample has survived critique.

The significance assigned in this study to the cultural and archaeological-historical context of the studied burials results from the undeniable importance of these factors for bioarchaeological interpretations. The conviction of processualists that a culture could be understood solely from how it treated its dead and the tools of quantitative analyses that processual archaeology reveled in at the time were later challenged. It seems, however, that taking into account the reservations put forward by post-processualists (Renfrew and Bahn 2008: 43; Johnson 2010: 48),[18] especially with regard to the mechanical treatment of burials and their relation to the social organization

[18] Rather than being adherents to a specific approach to archaeology, they share the critical view of the processual trend that dominated the methodological discourse in British and North American archaeology in the 1970s.

that created them (Lewartowski 2001: 136–138), there is a chance of reconstructing society fairly close to its actual form, although the emerging picture achievable is most certainly much less detailed than initially assumed.

In the case of the osteological material from archaeological excavations, Kom el-Dikka being no exception, one has to accept that it was probably not a random sample. The variety of grave types depending on the area of the cemetery is clear proof that the burials from Kom el-Dikka were not homogenous. However, it is also widely accepted that large series are more likely to be representative. After several decades of research, the excavation of the cemetery has reached a stage where the size of the excavated area and the significant number of graves examined should minimize the impact that a possible spatial differentiation could have on conclusions concerning the whole burial ground.

Therefore, with some reservations, the examined sample can be considered as representative of the population buried in the investigated part of the cemetery on Kom el-Dikka and it may be representative for the rest of the burial ground as well. It should be kept in mind that the conclusions from this study refer to a skeletal population (Jackes 2011: 107), which is necessarily a distorted representation of the population burying its dead in the necropolis. The question to be asked here is who are these people and how the living conditions in Alexandria in this period are reflected in them.

The historical and cultural setting of the cemetery and its dual-phased history, as well as evolution of grave types, have already been discussed in the first part of this work. It was not the only cemetery inside the so-called Tulunid walls and it probably covered a larger area extending beyond the modern boundaries of the archaeological site. The dead buried in this cemetery were most likely Muslims and it may be assumed that they represent a cross-section through the local Islamic society, including the poorest classes. The simple earth graves, for example, could have been intended for paupers. In this sense, however, the sample may have been biased, assuming, for instance, that members of the elite could have been buried in mausolea built at the site of Kom el-Nadura (Rodziewicz 1982: 40, 42), which is also inside the Tulunid circuit. And a part of the population, not necessarily proportionate to the size of the different groups of the deceased (distinguished by sex, age, property status, religious denomination, clan affiliation etc.), could have been laid to rest elsewhere [see *Fig. 23*] for a number of different reasons.

Selective diagenesis working on the skeletal material could have also affected the representativeness of the sample. Added to this are the methodological choices on the level of both archaeological and osteological research, destruction of part of the material as a result of both modern and 18th century building activity in the area of the site, as well as factors related to the individual abilities and expert knowledge of the explorers. While the degree to which all the described factors could have disturbed the representativeness of the sample cannot be easily assessed (see also *§ 3.2.2* and *§ 3.3.11*), an understanding of the limitations enables them to be addressed (Jackes 1993: 435; 2011: 107; Martin et al. 2013: 133) and in the end affects positively the credibility of conclusions drawn from the material.

3.3.11 Source of errors

The original intention was to carry out an error analysis, but such an approach would have implied a kind of formalized analysis leading to measurable results, preferably presented in numbers. It might have been feasible for singular analyses, in the case of stature, for instance, but when so many factors are taken into consideration as in this study, it would have probably clouded the issue. A total approach to errors would have been fully justified, had a single composite factor, such as one calculated on the base of a health index (Steckel, Sciulli, and Rose 2002), created for the project "The Backbone of History: Health and Nutrition in the Western Hemisphere" (Steckel and Rose 2002), been selected as the axis of the bioarcheological reasoning. Here, aiming at a comprehensive picture, this approach was given up in favor of sensitizing the reader to factors influencing the credibility of the results. However, a limited effort was made to identify disturbances and express them in numbers, restricted to basic values, thus enabling a formalized error analysis in the future, as needed, separately for each given issue.

Each evaluation is burdened by a potentially considerable error resulting from a set of factors as described in *§ 3.2*: poor state of preservation, severe fragmentation and commingling of bones, this beside the uncertainty deriving from method limitations. To deal with issues of poor bone preservation, reconstructed long-bone measurements were sometimes used instead of no measurements at all. Uncertainty of these was recorded on a four-step scale (0–3). The extreme values of the estimation error of the M1 measurements for individual bones were determined based on comparisons with undamaged bones. The maximum absolute uncertainty of the measurement estimations of femur, tibia, fibula and ulna length is presented in *Table 17A* and the maximum absolute uncertainty of estimations of the M1 measurement of radial and ulnar bones is shown in *Table 17B*.

The generally poor state of preservation of the skeletons affected also the credibility of sex assessments as well as characteristics as easy to describe (considering the adopted methodology) as *cribra orbitalia*. Uncertainty of these determinations was expressed on a three-grade scale but the same degree did not mean the same thing in view of the differences of both the object and methodology. Hence the values recorded should be treated merely as a hint, especially as it was decided to express the credibility of the evaluations in subjective terms. The best approximation of the uncertainty scale is: 0 – no uncertainty other than ascribed to the method, 1 – low to moderate uncertainty (other than from the applied method), 2 – high uncertainty, recommending caution.

Uncertainty in evaluating age-at-death was expressed primarily by the breadth of the range, although if additional error was anticipated, the subjective uncertainty of the determination was also indicated. The credibility of assessments of caries and enamel hypoplasia was dependent on the degree of wear of the crown of each tooth in addition to the state of preservation. Thus, the uncertainty of these characteristics was expressed subjectively on a three-grade scale, reflective of a combined evaluation of degree of wear, state of preservation of the tooth and the socket, and the uncertainty of the assessment of tooth position.

Table 17. Maximum uncertainty of estimation of length measurements (M1) of the A – humerus, femur, tibia, and fibula; B – ulna and radius; UL – level of uncertainty; *MUM* – maximum absolute uncertainty of estimation of the measurement

UL		*MUM*
0	→	0.0 cm
1	→	0.2 cm
2	→	0.5 cm
3	→	1.5 cm

UL		*MUM*
0	→	0.0 cm
1	→	0.2 cm
2	→	0.4 cm
3	→	1.0 cm

One cannot ignore that possible differences in skeletal morphology between the study population and the populations on the base of which the methods of analysis were created may have contributed to a higher uncertainty ascribed to these methods.

The results could have also been affected significantly by mistakes made in separating individuals when commingled. However, thanks to the relatively numerous set of individual assessments and the mutually independent nature of the bulk of the analyses, one may assume with some degree of certainty that this did not have much effect on the results. However, one should be aware that separating a set of bones into individuals taking into account morphological differences makes a skeleton potentially more "normal", reducing thus the chances of observing extreme cases of normal variation and pathological conditions that are manifested in lateralization and are grounded on massiveness, texture of the periosteum and build of the attachments.

Another source of error that is difficult to estimate, apart from the state of preservation of the skeletons and the commingling, are problems with attributing some of the graves to one of the general phases of the cemetery (Meyza 2000). The merging of the previously distinguished Lower and Middle Necropolises partly resolved these problems, especially with regard to the simple grave pits in the ground, but not fully, because the errors that were made tentatively during exploration could have been magnified several times during the interpretation and drawing of chronologically layered plans [see also *Fig. 7*].

It is not feasible to list all the possible sources of uncertainty. Those mentioned above are the ones considered to be the most significant for the present study. Others will be described as the need arises, wherever the discussion of the results will require explanation of observed interrelations.

3.4 RESULTS

The minimum number of individuals (MNI) established for the whole necropolis is 2603. Of this, 466 are attributed to the early phase (Lower Necropolis) and 2116 to the later phase (Upper Necropolis). In the case of 21 individuals, the chronological setting of their respective grave structures could not be determined, even approximately [*Table 18*].

Table 18. Sex assessment of the buried individuals by cemetery phase (percentage shares in parentheses); *n* – number of individual sex assessments

		♀	♂	?	Σ
Lower Necropolis	*n*	132	162	172	466
	(%)	(28.33)	(34.76)	(36.91)	(100)
Upper Necropolis	*n*	733	743	640	2116
	(%)	(34.64)	(35.11)	(30.25)	(100)
?	*n*	2	5	14	21
	(%)	(9.52)	(23.81)	(66.67)	(100)
Σ	*n*	867	910	826	2603
	(%)	(33.31)	(34.96)	(31.73)	(100)

3.4.1 Sex ratio

The sample consisted of 867 women and 910 men identified in the material under examination, that is, 33.31% and 34.96% respectively of the total number [see ***Table 18***]. Included in these numbers were adolescents whose sex could be determined owing to a 'male' skull or 'female' pelvis. For 31.73% (n=826) of the individuals analyzed, the sex could not be determined either because of poor preservation or young age.

The approximately 1:1 sex ratio for most species of living organisms that have offspring through sexual reproduction is explained by Fisher's principle (Seger and Stubblefield 2002: 9). Empirical data for human populations indicate that the ratio of women to men oscillates around this value (Bagnall and Frier 1994: 95). Therefore, a more or less equal representation of the sexes was expected in the assemblages from the cemetery on Kom el-Dikka. It turned out to be only slightly different from that expected for the cemetery assemblage as a whole (48.79% females and 51.21% males) but not for the constituent phases [see ***Table 18***].

The percentage of females (44.90%) from the Lower Necropolis was considerably lower than that of males (55.10%) [***Fig. 30***]. Although statistically insignificant for the assumed 95% confidence level (χ^2=2.23; p=0.14) [***Table 19***], the difference, compared to an ideal heterogeneous population, is sufficiently discernible to merit discussion. Possible reasons for the difference include:

- relatively high mortality among female adolescents and children; it would not have found reflection in the results of anthropological analyses owing to the limitations of macroscopic methods that allow sex assessment based on the skeletons of adult individuals only—individuals of such young age would simply not have been classified as females;[19]
- selective infanticide, common in many communities (Lewis 2007: 90–92), even today (Helman 2007: 179);
- some regionalization of the cemetery, that is, areas where a person of a specific sex would have been buried with greater probability; so far, however, there is no evidence in confirmation of this idea except for perhaps some local variations in the sex ratio (e.g., a superiority of female graves in Sector U of the Lower Necropolis phase (Mahler and Okularczyk 2016: 68);
- population mobility; for example, some of the men buried in the early phase of the cemetery on Kom el-Dikka may not have been Alexandria residents, having arrived, let's say, with the

Table 19. Sex ratio (%) by cemetery phase taking into consideration only individuals with determined sex; n – number of individuals; d – statistical error (in percentage points); CI_{lower} – lower limit of the confidence interval (in %); CI_{upper} – upper limit of the confidence interval (in %)

	Sex	n	%	d	CI_{lower}	CI_{upper}	χ^2	p
Lower Necropolis	♀	132	44.90	5.71	39.19	50.61	3.06	0.08
	♂	162	55.10	5.71	49.39	60.81	3.06	0.08
Upper Necropolis	♀	733	49.66	2.55	47.11	52.21	0.07	0.79
	♂	743	50.34	2.55	47.79	52.89	0.07	0.79

19 However, in certain cases sex assessment of adolescents is possible as well.

army; their families, including wives and children, would not have accompanied them, left behind at home, perhaps in Fustat;

- error resulting from a selective exploration of graves from this phase or else irregularities in sex assessment of poorly preserved skeletons, which were in much worse condition on average than in the case of the Upper Necropolis.

As said above, the sex ratio in the Upper Necropolis phase is virtually ideal: 49.66% females and 50.34% males among individuals of identified sex. Beside females, who constitute 34.64% (*n*=733), and males, who account for 35.11% (*n*=743) of the whole group, there were 30.25% (*n*=640) individuals of unidentified sex. The relatively small number of burials from the earlier phase—18.05% (n=466) compared to 81.95% (*n*=2116) for the Upper Necropolis—may be the reason why the differences in the sex ratio between the two phases turned out to be statistically insignificant (χ^2=2.226; p=0.1357). However, assuming the analyzed group is a random sample with regard to the skeleton population from the entire cemetery, then the observed differences in the sex ratio between the phases could have been conditioned by socio-cultural factors. In spite of not being statistically significant [see ***Table 19***], they do show that the Lower Necropolis could have somehow been different from the later phase.

A closer examination of the deviations called for the sex ratio to be analyzed separately for cist graves (the definition in this case including also stone covered earth graves) on one hand and earth graves without any additional structures on the other [***Fig. 31***]. Superstructures were ignored in their entirety because of the difficulties in linking them to specific subterranean structures, especially in the case of the Lower Necropolis.

The results [see ***Fig. 31***] show that the equal share of the sexes in the graves of the Upper Necropolis, as well as the unequal ratio of male to female burials in the Lower Necropolis, are reflected in the preferences of the sexes for specific forms of graves. In the case of the Upper Necropolis, there turned out to be an equal share of sexes in the three distinguished categories, but for the Lower Necropolis men were clearly more likely to be buried in cist graves. While the number of dead of both sexes was more or less equal for the category of earth graves [***Table 20***], constituting 51 females and 49 males (respectively 51.00% and 49.00%), the bulk of the cist graves belonged to men, that is, 57.78% (*n*=52). The women, constituting 42.22% (*n*=38) in this group, were not sufficiently less numerous for the observed ratio at a 95% confidence level to be statistically significantly different from the ideal ratio of 1:1: in the case of burials in cist graves, χ^2=2.1778 and p=0.140, and for skeletons from graves with unidentified structures, meaning those of a form not identified in the available documentation, χ^2=3.1154 and p=0.078. The difference in sex ratio was similarly insignificant statistically in relation to counterparts in the same categories for the Upper Necropolis, obtaining respectively χ^2=2.0034 and p=0.157 for cist graves and χ^2=2.2632 and p=0.133 for the group from graves with unidentified structure, assuming the same 95% level of confidence.

Burials in graves of unknown form constitute a fairly large group [see ***Table 20***]. It seems safe, however, to assume that the bulk of the analyses not attributed to a specific grave structure concerned material from the cist graves, this based on observed patterns of cemetery exploration and documentation before the mid 1980s when most of the archaeologically unidentified structures present in the anthropological analyses were discovered (the issue is discussed in greater detail above, see *§ 2.1*). Once the unidentified graves with 41.35% women (*n*=43) and 58.65% men

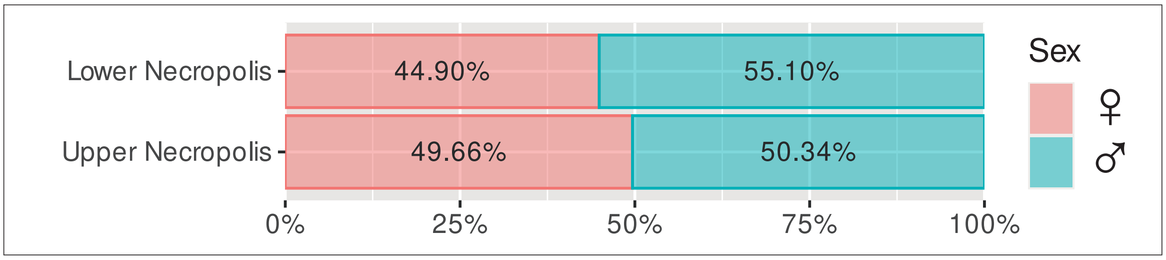

Fig. 30. Sex ratio of the buried individuals by cemetery phase

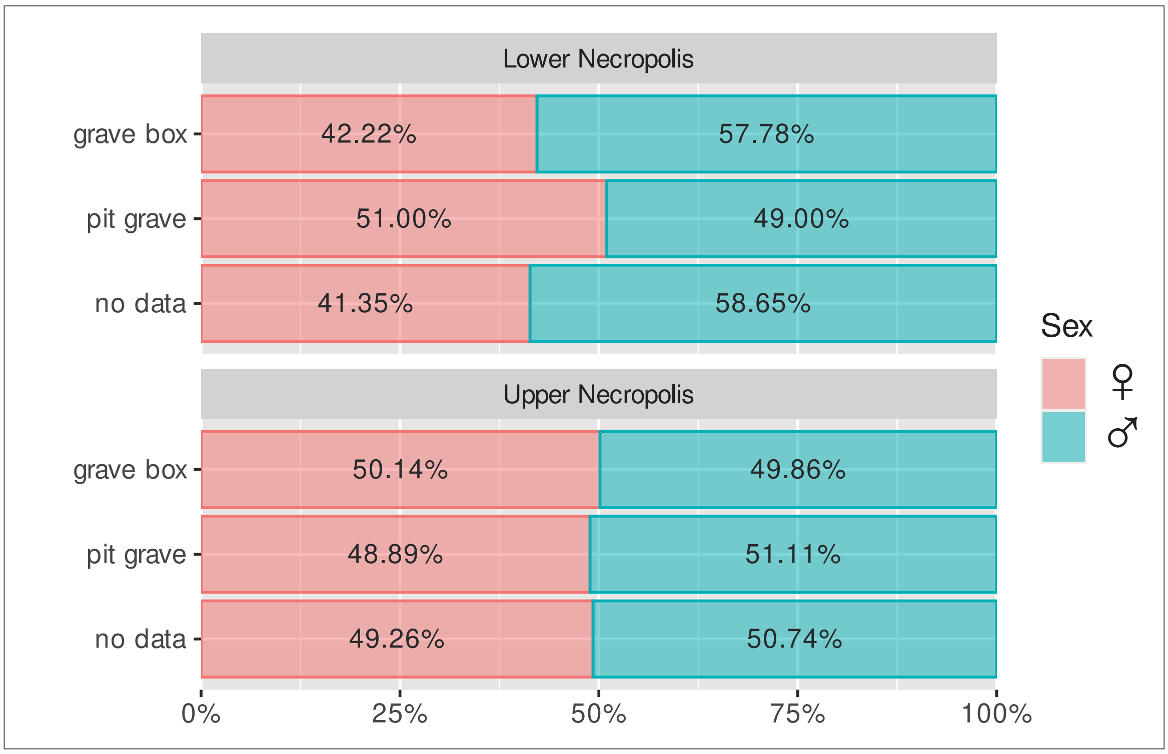

Fig. 31. Sex ratio of individuals buried in graves with stone casing versus those in earth graves (without covering), by cemetery phase

(*n*=61) are included in the set of cist graves, assuming that the above reasoning is correct, the result will be, respectively, 41.75% and 58.25%, emphasizing thus the observed preferences of the sexes regarding grave form. Conversely, if all the unidentified graves are attributed to the earth grave category, the resulting ratio of, respectively, 46.08% to 53.92% still suggests the postulated preference. One should acknowledge the possibility of other divisions of the unidentified graves, but despite no statistical significance of the observed differences, the most probable conclusion is that, in the Lower Necropolis phase, there was an actual preference for interring men, more often than women, in the stone cist graves.

On a final note, research by Phillip L. Walker, John R. Johnson, and Patricia M. Lambert (1988) has demonstrated that taphonomic processes should not affect the sex ratio. Hence the described differences should not be attributed to diagenetic factors working selectively with regard to the sexes.

Table 20. Sex ratio of individuals buried in graves with stone casing versus those in earth graves (without covering), by cemetery phase; *n* – number of individuals

	Sex	Grave box		Pit grave		?		Σ	
		n	%	*n*	%	*n*	%	*n*	%
Lower Necropolis	♀	38	23.90	51	31.87	43	29.25	132	28.33
	♂	52	32.70	49	30.63	61	41.50	162	34.76
	?	69	43.40	60	37.50	43	29.25	172	36.91
	Σ	159	100.00	160	100.00	147	100.00	466	100.00
Upper Necropolis	♀	355	33.91	44	34.92	334	35.42	733	34.64
	♂	353	33.72	46	36.51	344	36.48	743	35.11
	?	339	32.38	36	28.57	265	28.10	640	30.25
	Σ	1047	100.01	126	100.00	943	100.00	2116	100.00
?	♀	0	0.00	0	0.00	2	10.00	2	9.52
	♂	0	0.00	0	0.00	5	25.00	5	23.81
	?	0	0.00	1	100.00	13	65.00	14	66.67
	Σ	0	0.00	1	100.00	20	100.00	21	100.00

3.4.2 Age-at-death

Age-at-death of the individuals from the Kom el-Dikka graves is given according to the six age brackets making up the human life cycle adopted in this research. The results are charted in *Fig. 32* and summed up in *Table 21*. The counts of individuals are given using real numbers. Non-integer values reflect a situation in which the range of age-at-death evaluation of given individuals extends beyond the age brackets assigned to particular age categories (see *§ 3.3.4*). In view of their biological nature, the age brackets in years, here in parentheses, are used solely for reference.

Considering that sex determination of pre-adolescent individuals based on bone morphology is not credible, children formed the most numerous group among individuals of undetermined sex. Those dead at the age of zero to 20, a sum total of 804.88 cases, constituted 31.02% of the total number of examined 2595 individuals, who, according to the macroscopic determination of age-at-death, were born alive. In this group, keeping to the principle that adolescent sex determination requires a 'male' skull or 'female' pelvis, the number of females identified was 82.72 to just 30.69 males. The determinations summed up to 113.41 (14.09%) of skeletons classified here as children and made up 6.38% among the 1777 successful determinations of sex.

The bulk of the 818 unsuccessful sex determinations, 691.47 (84.53%), was due presumably to the young age (under 20 years) of the deceased; only 126.52 (15.47%) resulted from other factors. The numbers for the Lower Necropolis were, respectively, 123.13 (72.01%) and 47.87 (27.99%), and for the Upper Necropolis, 564.34 (89.15%) and 68.66 (10.85%) [*Table 21*].

Table 21. Frequencies of age-at-death brackets for individuals buried at the necropolis, taking into account the division into two chronological phases and determined sex; *n* – number of individuals

	Sex	0–7		7–14		14–20		20–35		35–55		55–x		Σ	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Lower Necropolis	♀	0.00	0.00	0.00	0.00	13.70	10.38	37.06	28.08	62.18	47.10	19.06	14.44	132	100.00
	♂	0.00	0.00	0.30	0.19	5.70	3.52	37.56	23.19	76.71	47.35	41.73	25.76	162	100.00
	?	78.34	45.82	28.49	16.66	16.30	9.53	17.46	10.21	20.81	12.17	9.61	5.62	171	100.00
	Σ	78.34	16.85	28.79	6.19	35.70	7.68	92.08	19.80	159.69	34.34	70.40	15.14	465	100.00
Upper Necropolis	♀	0.00	0.00	0.00	0.00	69.03	9.42	271.95	37.10	245.35	33.47	146.67	20.01	733	100.00
	♂	0.00	0.00	1.00	0.13	23.69	3.19	200.61	27.00	314.80	42.37	202.90	27.31	743	100.00
	?	381.84	60.32	94.06	14.86	88.45	13.97	20.87	3.30	28.28	4.47	19.51	3.08	633	100.00
	Σ	381.84	18.11	95.06	4.51	181.16	8.59	493.43	23.40	588.43	27.90	369.09	17.50	2109	100.00
?	♀	0.00	0.00	0.00	0.00	0.00	0.00	2.00	100.00	0.00	0.00	0.00	0.00	2	100.00
	♂	0.00	0.00	0.00	0.00	0.00	0.00	1.50	30.00	3.50	70.00	0.00	0.00	5	100.00
	?	2.00	14.29	0.46	3.30	1.54	10.99	5.06	36.12	4.56	32.55	0.39	2.76	14	100.00
	Σ	2.00	9.52	0.46	2.20	1.54	7.33	8.56	40.75	8.06	38.37	0.39	1.84	21	100.00
Σ	♀	0.00	0.00	0.00	0.00	82.72	9.54	311.01	35.87	307.53	35.47	165.73	19.12	867	100.00
	♂	0.00	0.00	1.30	0.14	29.39	3.23	239.67	26.34	395.01	43.41	244.63	26.88	910	100.00
	?	462.18	56.50	123.00	15.04	106.29	12.99	43.38	5.30	53.64	6.56	29.50	3.61	818	100.00
	Σ	462.18	17.81	124.30	4.79	218.40	8.42	594.07	22.89	756.18	29.14	439.87	16.95	2595	100.00

A frequency chart of age-at-death categories presented separately for each distinguished phase of the cemetery [see *Fig. 32*], in summary form for the two sexes together, demonstrates that compared to the Lower Necropolis, the Upper Necropolis has:

- a higher percentage of young adults' death;
- a lower share of mature individuals among the deceased;
- a larger group reaching an advanced age;
- slightly larger share of three age brackets for children in the total number of the deceased.

Looking at these changes, one assumes intuitively that the inhabitants of Alexandria experienced a slight improvement of living conditions. Despite the relatively small size of groups distinguished in the sample from the Lower Necropolis, the charted differences in age category ratios between the two phases have proved statistically significant at the assumed confidence level of 95% (χ^2=11.805; p=0.038; 5 degrees of freedom). The rising number of individuals of advanced age in the case of the Upper Necropolis (from 15.14% to 17.50%) supports the intuitive assumptions, while the growing share of the youngest in the total number of buried individuals (from 30.72% to 31.21%) was sufficiently low not to require an additional explanation.

The skeletal material from the Upper Necropolis was generally in a much better state of preservation compared to the bones from the earlier phase (as discussed above, see *§ 3.2.2*). The almost complete lack of any differences in the proportions between adult and child skeletons between phases is surprising considering that post-depositional processes at work should have resulted in the smaller child bones, especially of the youngest individuals (0–7 year category), being presumably more likely to disintegrate completely when not inside a grave box. Box interments were much more frequent in the Upper Necropolis phase. Moreover, the difficult excavation conditions at the Kom el-Dikka site may have resulted in pit graves occasionally going unobserved. The exceptionally thorough work done in Sector

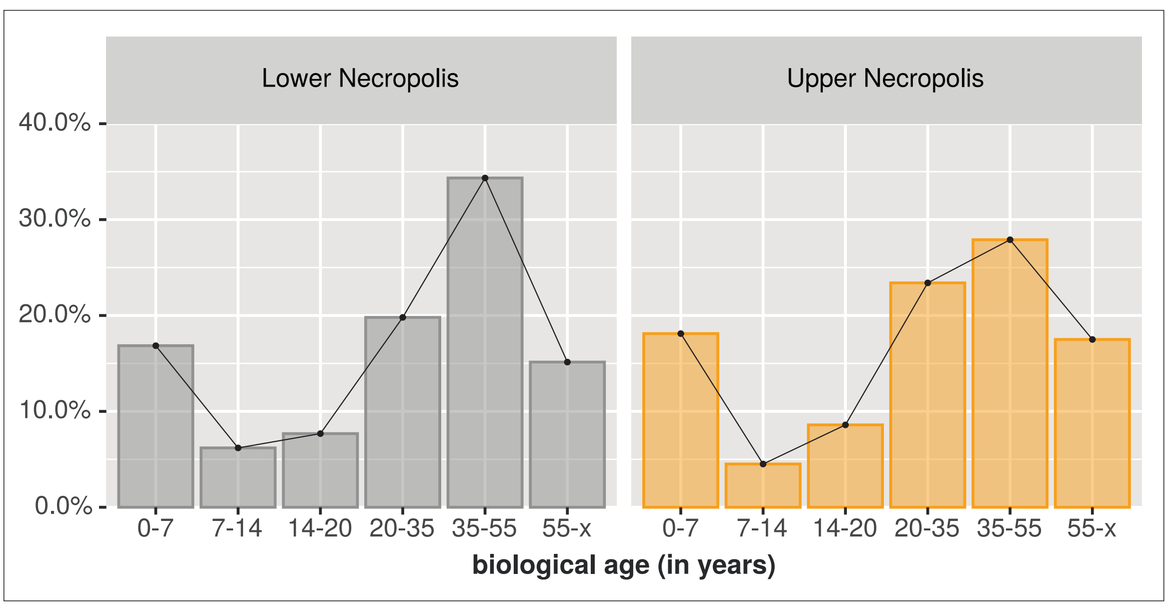

Fig. 32. Percentage share of individual age-at-death bracket groups among the individuals buried in the necropolis, taking into account the division into two chronological phases

Table 22. Frequencies of different age-at-death brackets for adult individuals buried in the cemetery, taking into account the division into two chronological phases and determined sex; *n* – number of individuals

	Sex	20–35		35–55		55–x		Σ	
		n	%	*n*	%	*n*	%	*n*	%
Lower Necropolis	♀	37.06	31.33	62.18	52.56	19.06	16.11	118.30	100.00
	♂	37.56	24.08	76.71	49.17	41.73	26.75	156.00	100.00
	?	17.46	36.47	20.81	43.46	9.61	20.07	47.87	100.00
	Σ	92.08	28.58	159.69	49.57	70.40	21.85	322.17	100.00
Upper Necropolis	♀	271.95	40.96	245.35	36.95	146.67	22.09	663.97	100.00
	♂	200.61	27.93	314.80	43.83	202.90	28.25	718.31	100.00
	?	20.87	30.40	28.28	41.18	19.51	28.42	68.66	100.00
	Σ	493.43	34.01	588.43	40.55	369.09	25.44	1450.95	100.00
?	♀	2.00	100.00	0.00	0.00	0.00	0.00	2.00	100.00
	♂	1.50	30.00	3.50	70.00	0.00	0.00	5.00	100.00
	?	5.06	50.57	4.56	45.57	0.39	3.86	10.00	100.00
	Σ	8.56	50.34	8.06	47.39	0.39	2.27	17.00	100.00

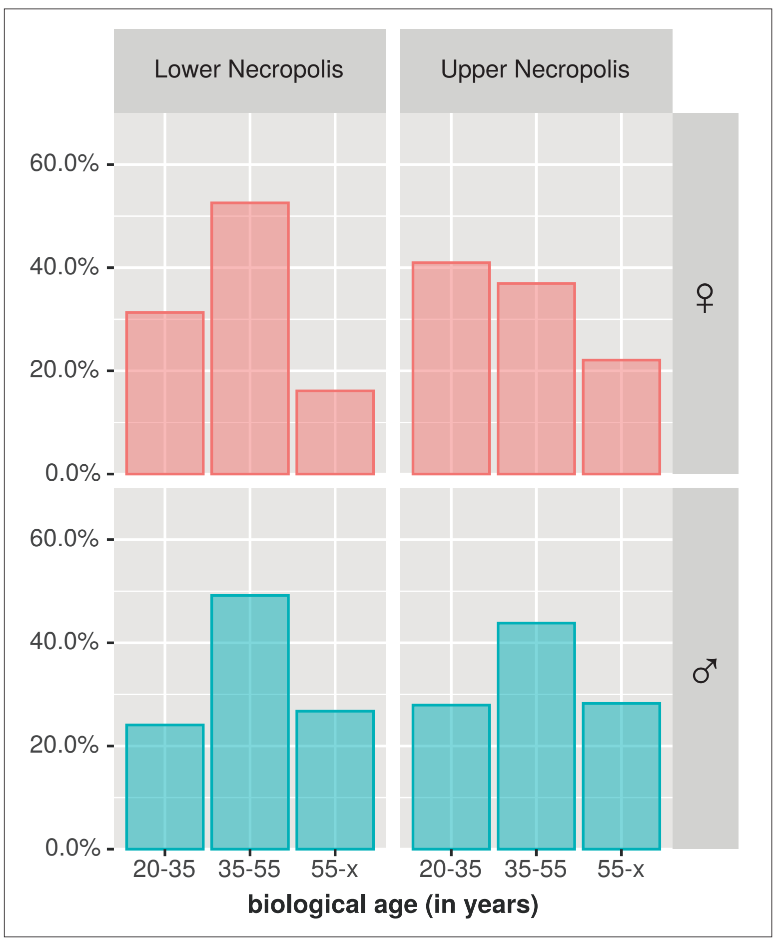

Fig. 33. Percentage share of age-at-death categories for adult individuals buried in the necropolis, taking into account the division into two chronological phases and determined sex

GS (Meyza 2000) exemplifies the case. The number of pit graves discovered there, relative to the excavated area, was much higher than elsewhere on the site [see ***Figs 8, 9***; for A3 format see ***Plans A, B***]. Here, too, one should expect that the smaller skeletons, particularly of the youngest children, could have gone unnoticed.

Furthermore, the smaller number of females compared to the males in the Lower Necropolis phase (see ***§ 3.4.1***) would seem to be an additional factor justifying a lower number of children in this assemblage. However, should one modify the total number of individuals for the Lower Necropolis by lowering the number of males to match the count of females,[20] the share of the youngest children (0–7 years) would amount to 18.01% (16.85% before correction), which is surprisingly in keeping with the 18.11% established for the Upper Necropolis. The same is true of adolescent individuals (14–20 years), where the share 7.68% after correction is 8.21%, which is very close to the 8.59% established for the later phase. Not so for the older children (7–14 years), where after correction, the share of individuals in this bracket grew from 6.19% to 6.62%, which is clearly more compared to the 4.51% of the later phase.

The differences are too meager to support conclusions other than the observation that in view of the expected higher relative number of children following the transition to the Upper Necropolis phase and keeping in mind selective bone preservation,[21] the generally equal share of non-adult skeletons—30.72% for the Lower Necropolis and 31.21% for the later phase—could indicate a higher mortality of children at the time when the cemetery was first established. The anticipated increase is also a factor of the more-than-10-percentage-point difference in the sex ratio for the Lower Necropolis, and the conjectural guess that this difference should be reflected in the number of child burials. However, one could also take a different view that would not anticipate such an increase. For example, at a time of religious conversion within the Lower Necropolis horizon, in mixed-religion married couples, women brought up in a different faith could have been buried separately, but their children need not have been treated as different. In this case, the observed absence of a difference in the percentage share would be an indication of no changes in the mortality of the youngest.

In the case of children, the differences of the age brackets percentage distribution between cemetery phases, at a 95% confidence level, were, as one could expect, statistically insignificant (χ^2=2.9601; p=0.2276; 2 degrees of freedom). For adult individuals, aged 20 and more, the evident changes between the Upper and Lower Necropolises [see ***Fig. 32***] were statistically significant (χ^2=8.7933; p=0.01232; 2 degrees of freedom). In view of these changes, the frequency of particular age brackets among adult individuals was investigated separately. Female individuals turned out to be responsible for most of the observed differences [***Table 22***], hence the analysis of the distribution of the relative number within an age-at-death bracket in terms of the sex of the buried individuals [***Fig. 33***].

For the men, a slight increase in the share of dead young adult males was noted between the phases (from 24.08% to 27.93%); a slightly more pronounced decline was noted for the mature age (from 49.17% to 43.83%). However, owing to a simultaneous rise in the number of individuals reaching an advanced age (from 26.75% to 28.25%), there are no strong premises to see any

[20] This assumes that the sex ratio for the Lower Necropolis would not change were the sex of all individuals from a given phase determined with certainty.

[21] It is difficult to specify relevant values.

Table 23. Sex ratios for age-at-death brackets for adult and adolescent individuals buried in the necropolis, taking into account the division into two chronological phases; number of males multiplied by a coefficient compensating for the unequal share of sexes separately for each phase of the necropolis (amounting to 0.8163 for the Lower and 0.9879 for the Upper Necropolis); *n* – number of individuals

	Sex	14–20		20–35		35–55		55–x	
		n	%	*n*	%	*n*	%	*n*	%
Lower Necropolis	♀	13.70	74.64	37.06	54.72	62.18	49.82	19.06	35.88
	♂	4.65	25.36	30.66	45.28	62.62	50.18	34.06	64.12
Upper Necropolis	♀	69.03	74.68	271.95	57.85	245.35	44.10	146.67	42.25
	♂	23.40	25.32	198.17	42.15	310.98	55.90	200.44	57.75

changes in wellbeing of the males buried on Kom el-Dikka. The differences, assuming a 95% level of confidence, proved to be statistically insignificant (χ^2=1.619; *p*=0.4451; 2 degrees of freedom).

The differences in the age-at-death shares observed between the two phases of the cemetery in the case of females were much more distinct, both at first glance [see ***Fig. 33***] and from a statistical point of view. These differences were statistically significant (χ^2=10.275; *p*=0.0059; 2 degrees of freedom) for the assumed 95% level of confidence. Therefore, females buried in the Upper Necropolis could have experienced a significant change in their living conditions compared to the period of the Lower Necropolis. This statement will be true only if the examined sample is even roughly representative of the dead members of the Islamic community of Alexandria, a community defined by the timeframe for the two phases of the cemetery as discussed above (see ***Chapter 2***).

The higher percentage of young adults (rising from 31.33% to 40.96%), the declining share of mature individuals in the overall number of females from the graves (from 52.56% to 36.95%) and the higher relative number of individuals of advanced age (from 16.11% to 22.09%) suggest improved conditions for those reaching a mature age, accompanied simultaneously by a growing threat to the youngest females. In modern times, pregnancy, birth and puerperium have been probably the biggest threats to women at the reproductive age, differentiating them from men. Even today, in the poorest regions of the world, one out of six women dies of related reasons (Ronsmans, Graham, Lancet Maternal Survival Series steering group, others 2006: 1189–1190). Therefore, the observed situation could be cautiously explained by cultural changes leading to a higher mortality of women in the later phase for reasons generally linked to childbirth.

To be noted in this context are the results of research on the 19th century parish books from Nova Raca in Croatia, according to which only 5.2% of the women there died of causes linked to childbirth.[22] The relatively higher death rate among young females observed during anthropological research at a nearby cemetery from the 14th–18th centuries was explained rather by hunger and unequal nutritional status of the sexes (Slaus 2000: 195, 207–208). The current percentage of females died in childbirth and puerperium for sub-Saharan Africa is very similar, amounting to 6.25%, taking into consideration only death due to pregnancy (Ronsmans et al. 2006: 1190).

In spite of their indistinctiveness, the changes observed for men showed the same direction as in the case of females. It is possible, therefore, that the changes in the living conditions of

[22] There is no data on females died of complications linked to pregnancy.

Alexandrians of this age were of a more universal character. It seems that life in the 11th–12th century coastal city was generally more difficult for young adults and gentler for the elderly, compared to conditions in the 9th–10th century.

To look at the differences between the age-at-death and sex of the deceased with greater discretion, the sex ratios for particular age brackets were tabularized [***Table 23***]. The numbers used were evened by the phase of the necropolis to eliminate the influence of summary sex ratios (for details see *§ 3.3.4*). The observed disproportions were no longer so distinct once this compensation was applied.

The ratio of female to male skeletons for the youngest age bracket, 14–20 years, became practically identical for the two cemeteries (74.64% to 25.36% and 74.68% to 25.32%). Keeping in mind certain reservations concerning the manifesting of sexual traits on skeletons of adolescent individuals,[23] the ratios indicate a definitely higher mortality among females or at least no change in the relative mortality of individuals of both sexes between the two phases of the cemetery in this age group.

Tests of sex ratios also did not show significant differences between the two cemetery phases in any other category. For the 20–35 years bracket: χ^2=0.23596 and p=0.6271, for 35–55 χ^2=1.3477 and p=0.2457, and for 55–x χ^2=0.77136 and p=0.3798. This failure[24] is presumably due to a relatively small number of skeletons in particular categories, especially evident in the case of burials from the Lower Necropolis [see ***Table 23***].

Despite no confirmation from statistical tests, these observations in the case of a simple frequency distribution are reflected in the juxtaposed ratios. The small diachronic growth in the share of females aged 20–35 years (from 54.72% to 57.85%), compared to a more distinct drop for the 35–55 age brackets (from 49.82% to 44.10%) and the relatively growing number of females reaching 55 years and more (from 35.88% to 42.25%), testify to living conditions for females improving between the Lower and the Upper Necropolis, at least for those who reached the 35–55 age bracket, this especially pronounced when compared to male status, which as stated already [***Fig. 33***], remained practically unchanged from the point of view of the age-at-death of the dead buried in the cemetery.

3.4.3 Stature

Long-bone length measurements essential for selected methods of stature reconstruction to be applied were taken from only 512 skeletons of adult individuals, this owing to the poor state of preservation of the osteological material in general. Stature means were tabularized by sex and cemetery phase [*Table 24*], while the frequencies for centimeter intervals were charted separately for men and women, retaining the division into cemetery phases [***Fig. 34***].

[23] The effectiveness of macroscopic methods of sex determination using bones in the case of adolescent individuals may depend on itself, that is, on the sex of the deceased. Furthermore, it is most probably heavily dependent also on the population under study.

[24] It would be true also for a less conservative approach to testing ratios, according to which the compensation coefficient (see *§ 3.3.4*) would be calculated and applied in the case of the less numerous sex. Instead of lowering the number of skeletons, as in the case of males, it would increase the count of females by 22.73% for the Lower and by 1.36% for the Upper Necropolis. After compensation, there would be n=45.48 females in the 20–35 years age bracket in the case of the Lower and n=275.65 in the case of the Upper Necropolis with χ^2=0.27959 and p=0.597. For the 35–55 age bracket, it would give χ^2=1.5972 and p=0.2063, while the counts for females would be n=76.31 and n=248.69 respectively. For the age of 55 and more, the test would give χ^2=0.91895 and p=0.3378, and the counts for females would amount to n=23.39 for the early phase and n=148.66 for the later one.

Table 24. Mean stature of individuals ($\bar{x}$) by cemetery phase, taking sex into consideration; n – number of individuals; s – standard deviation; x_{min} – minimum stature calculated; x_{max} – maximum stature calculated; $\overline{MUM}$ – mean maximum uncertainty of estimation of stature resulting from the uncertainty of long bone measurements used for stature reconstruction; $\overline{SEE}$ – mean standard error of the estimate resulting from the application of regression equations

	Sex	n	$\bar{x}$	s	x_{min}	x_{max}	$\overline{MUM}$	$\overline{SEE}$
Lower Necropolis	♀	17	155.90	6.02	148.00	174.00	0.44	3.62
	♂	23	167.10	5.53	159.00	179.00	0.67	4.32
Upper Necropolis	♀	216	157.40	6.48	138.00	182.00	0.34	3.70
	♂	208	169.50	5.51	152.00	187.00	0.30	4.20
?	♀	1	169.00	–	169.00	169.00	4.04	2.92
	♂	1	161.00	–	161.00	161.00	1.39	4.66

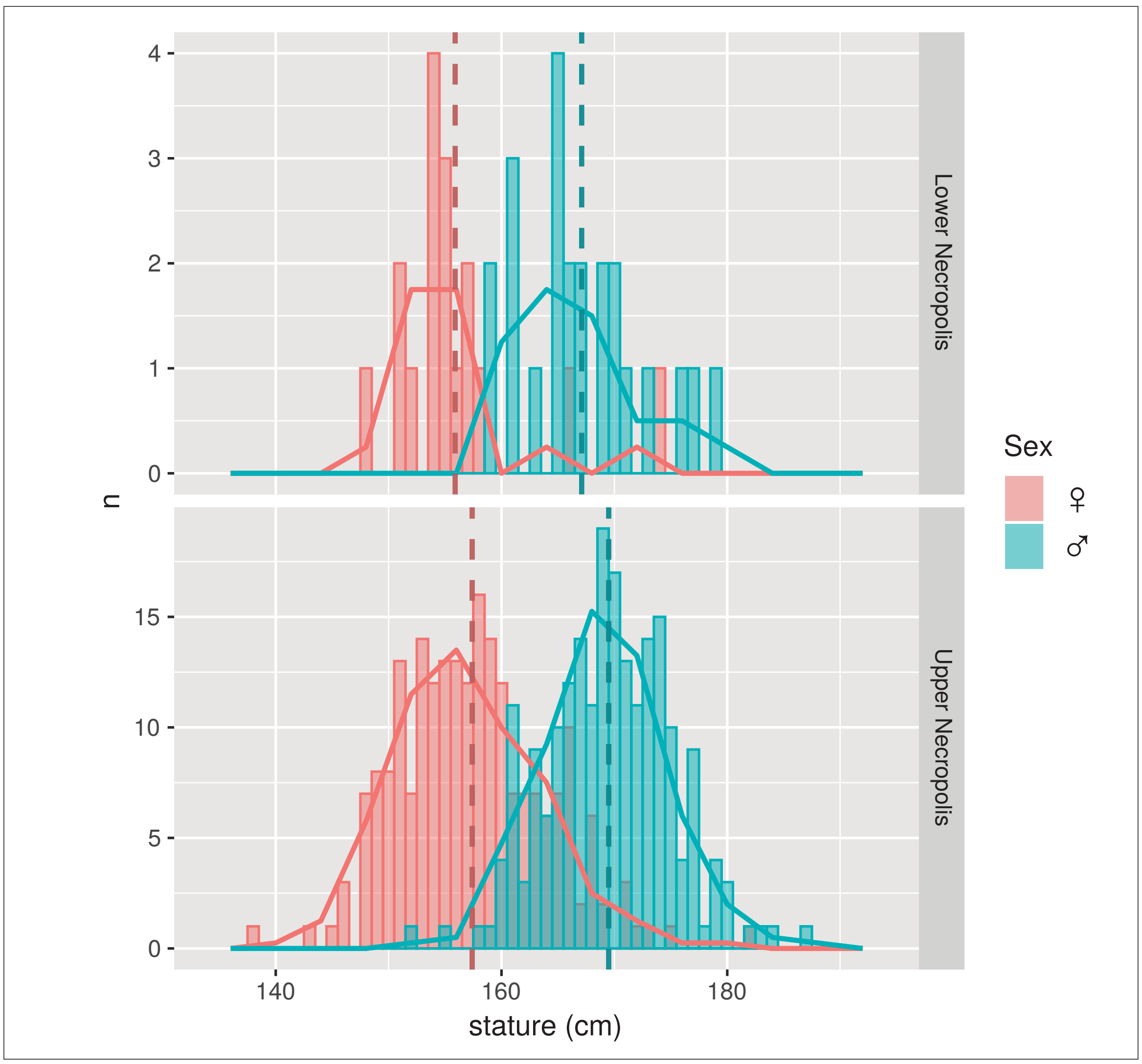

Fig. 34. Histograms of the stature of individuals buried on Kom el-Dikka by sex, separately for the two cemetery phases; continuous lines represent a partly smoothed frequency; dashed lines indicate mean values obtained for each sex

In the case of the Lower Necropolis, the stature estimation counts did not exceed 30, amounting to 17 and 23, for female and male skeletons respectively. 30 is an arbitrary limit beyond which, in tests that require a normal distribution of variables, one can cautiously assume that the condition has been met (Ruxton 2006: 688). Histograms of stature estimations are slightly skewed [see *Fig. 34*], but in general their shape seems to be close to normal. Hence the decision to use the Student's t-test in the version for independent variables, applying Welch's correction for series with a different variance. In the case of the Upper Necropolis, having 216 female and 208 male skeleton estimations created a suitable basis for assuming the normality of their distribution. This is from the point of view of both the Central Limit Theorem and the histogram [see *Fig. 34*]. The assumed 95% confidence level for the two-tailed test requires $p<0.05$ to be able to speak of significant differences between the averages.

None of the differences obtained for individuals of the same sex between the phases turned out to be statistically significant, although the result obtained for males with t=1.9865, p=0.0572, with an average stature difference of 2.4 cm, was very close to this. It shows a positive trend in the studied value, which in turn can be considered cautiously as a reflection of a positive change in the wellbeing of the Muslim population between the two discussed periods. For women, this difference of only 1.5 cm, despite being unsupported by the statistics at t=0.9802 and p=0.3393, also seems to have a slightly positive relationship over time. A small increase in female stature, accompanied by a much more pronounced increase in this value in the case of males, may be evidence of improved living conditions. Male organisms, more sensitive to nutritional stress, would have been affected by the improved living conditions more strongly than female ones, which are less responsive in terms of stature (Frayer and Wolpoff 1985: 431–432; Wolański 2008: 125).

One should bear in mind that the poor condition of the osteological material, especially in the case of the Lower Necropolis, resulted in stature estimations for male individuals from this phase being additionally burdened with more than twice the average maximum uncertainty of estimation ($\overline{MUE}$) noted for the Upper Necropolis owing to the uncertainty of long bone measurements used for the reconstruction. However, even in this case, the $\overline{MUE}$ value was many times lower than the uncertainty resulting from the mean standard error of the estimate ($\overline{SEE}$) inherent to specific equations included in the stature reconstruction methods employed. Moreover, in the case of one woman from the Lower Necropolis (grave DN-NN-A29, specimen 1), a clear anomaly in the ulnar-to-tibial bone length proportions (172 mm to 385 mm) excluded her from the calculations. Exclusion of this extreme result (132 cm stature) from the already very small series considerably impacted the obtained mean.

The difference between male and female mean stature grew from 7.18% to 7.69% between the cemetery phases. Interpreting this value within intervals describing the condition of the population depending on the dimorphism value of this trait, one may assume that the individuals buried in the Upper Necropolis phase belonged to a community that was stable both economically and socially or otherwise in the first phase of improving conditions following a previously adverse situation (7.5%–8.5% interval). With a result of 7.18%, the Lower Necropolis population was in transition, with living conditions either (a) deteriorating from good or (b) improving from worse (7.0%–7.5% interval) (Wolański 2008: 126).

The positive trend in mean stature observed between the Lower and Upper Necropolis indicates that the changes in the community associated with the Lower Necropolis should also be cautiously assumed as going in a positive direction. Hence the scenario (a) of the second mentioned interval should rather be rejected. In light of the above, the percentages describe a population with a stronger growth in girls' stature in the earlier phase, preceding probable stabilization in the later phase.

3.4.4 Dentition

Due to the limitations of available analyses (described above, see *§ 3.3.8*), the set of odontological data used here included only 229 individuals (see also *§ 3.2*; 17 out of 248 individuals presented in the odontological part of the catalog in Appendix B were adolescents and the age-at-death of another two could not be assessed). Out of this number, 33 were buried in graves of the Lower Necropolis, 192 in structures of the Upper Necropolis, and four could not be identified to chronological phase. 108 females and 114 males were distinguished in the assemblage as a whole, and the sex of seven skeletons could not be reliably determined with macroscopic methods.

3.4.4.1 *Caries and tooth wear*

Caries and tooth wear should be considered in age-at-death context in view of the tendency for these conditions to become aggravated over time. However, the series was too small to be analyzed in any other division than adults and children, and since only one out of 17 non-adults included in the catalog in Appendix B was assigned to the Lower Necropolis phase, it also proved impossible to compare carious lesions across phases in the children's age category. Therefore, all considerations of caries and tooth wear in this study were based on adult individuals, that is, individuals estimated to have been over 20 years old (see above, *§ 3.3.8*). Excluding from the statistics permanent teeth belonging to adolescent individuals eliminated the associated unknown factor disturbing the analysis, that is, 16 times less cases from the Lower Necropolis. This division into adults and children should allow for potential future comparisons with the results of analyses from other sites (see methodological remarks in Lorkiewicz 2012: 125).

Carious lesions were observed in 71 adult individuals, constituting 31.00% of all those examined [***Table 25***]. The percentage was even higher in the case of the Lower Necropolis, 36.36% (n=33), whereas for the Upper Necropolis it was just 29.69% (n=192). The difference, where χ^2=0.5903 and p=0.4423, proved statistically insignificant in the test of proportions. In this context, the lack of statistical significance is not surprising, also in the case of the less numerous samples for females (χ^2=0.35583 and p=0.5508), 35.71% (n=14) for the early phase and 27.96% (n=93) for the later phase, and for males (χ^2=0.000859 and p=0.9766), respectively 33.33% (n=18) and 32.98% (n =94) individuals. One should note that the small sample from the Lower Necropolis, coupled with the evidently worse state of preservation of skeletons from this phase,[25]

[25] The apparently poorer condition of the skeletons was matched by the rather explicit ratio of the number of teeth to empty tooth sockets indicating post mortem loss. In the case of the Lower Necropolis teeth constituted 66.92% of the sum (n=520), dropping to 61.58% (n=2837) in the Upper Necropolis phase. The difference, at a 95% confidence level, turned out to be statistically significant (χ^2=5.3493 and p=0.02073). It should be noted that the observed interrelation, taking into consideration the sex of the deceased, is no longer so clear. While a similar trend is observed for the males, 69.58% (n=263) and 61.54% (n=1508) respectively for the Lower and Upper Necropolis, the proportions for females appear to be reversed, respectively 61.23% (n=227) and 62.00% (n=1279). But while the values observed for the males were statistically significant (χ^2=6.197 and p=0.0128), they were not so for the females (χ^2=0.048218 and p=0.8262).

Table 25. Frequency of carious lesions compared to healthy elements of the chewing apparatus, divided by cemetery phase and taking into consideration determined sex; *n* – number of cases observed; *ni* – number of individuals for whom assessment of the chewing apparatus was possible; *ci* – individuals with carious lesions; *tp* – number of tooth positions; *il* – teeth lost intravitally; *pl* – teeth lost post mortem; *t* – teeth; *ct* – teeth with carious lesions; I_{CE} – index I-CE (index of caries e*t extractio*)

	Sex	*ni*	*ci*		*tp*	*il*		*pl*		*t*		*ct*		I_{CE}
			n	%		*n*	%	*n*	%	*n*	%	*n*	%	
Lower Necropolis	♀	14	5	35.71	243	16	6.58	88	36.21	139	57.20	8	5.76	9.88
	♂	18	6	33.33	279	16	5.73	80	28.67	183	65.59	8	4.37	8.60
	?	1	1	100.00	30	0	0.00	4	13.33	26	86.67	3	11.54	10.00
	Σ	33	12	36.36	552	32	5.80	172	31.16	348	63.04	19	5.46	9.24
Upper Necropolis	♀	93	26	27.96	1501	222	14.79	486	32.38	793	52.83	51	6.43	18.19
	♂	94	31	32.98	1703	195	11.45	580	34.06	928	54.49	60	6.47	14.97
	?	5	0	0.00	50	0	0.00	24	48.00	26	52.00	0	0.00	0.00
	Σ	192	57	29.69	3254	417	12.81	1090	33.50	1747	53.69	111	6.35	16.23
?	♀	1	1	100.00	32	0	0.00	1	3.12	31	96.88	1	3.23	3.12
	♂	2	0	0.00	40	4	10.00	22	55.00	14	35.00	0	0.00	10.00
	?	1	1	100.00	8	0	0.00	7	87.50	1	12.50	1	100.00	12.50
	Σ	4	2	50.00	80	4	5.00	30	37.50	46	57.50	2	4.35	7.50
Σ	♀	108	32	29.63	1776	238	13.40	575	32.38	963	54.22	60	6.23	16.78
	♂	114	37	32.46	2022	215	10.63	682	33.73	1125	55.64	68	6.04	14.00
	?	7	2	28.57	88	0	0.00	35	39.77	53	60.23	4	7.55	4.55
	Σ	229	71	31.00	3886	453	11.66	1292	33.25	2141	55.10	132	6.17	15.05

could have substantially affected the results. Therefore, the relative drop in the percentage of cases of caries should be associated with errors due to this rather than any real changes of living conditions taking place in Alexandria over time. Interpreting differences between the sexes similarly in this respect, it was assumed that the observed drop in the percentage of cases is doubtful and should not be taken into account in the reasoning. However, it is impossible to ignore the superiority of males in terms of caries frequency in the Upper Necropolis phase, which is at odds with the regularities known from other sites (Lorkiewicz 2012: 121). Nonetheless, it is not a statistically significant difference (χ^2=0.55634 and p=0.4557), and the most probable explanation lies in the relatively small series and the poor preservation of the dentition.

Looking at caries from the point of view of individual teeth and tooth positions, as in successive columns of the tabular presentation [see ***Table 25***], technically resolved the problem of the small size of the series, but did not increase considerably the number of positive observations: only eight for females and the same number for males in the case of the Lower Necropolis. In this context, the slight percentage growth of teeth with caries in the set of all teeth, observed for the younger phase, should be treated with reserve. The total share was 5.46% (n=348) for the Lower Necropolis and 6.35% (n=1747) for the Upper Necropolis, and the difference between phases turned out to be statistically insignificant (χ^2=0.3985 and p=0.5279 at 95% level of confidence). These proportions were for females 5.76% (n=139) and 6.43% (n=793) respectively, and for males, 4.37% (n=183) and 6.47% (n=928). None of these differences between the phases was statistically significant, although the one for males appears to be distinct.

The third and last element of the summary [see ***Table 25***] was the I-CE index (index of caries et extractio), the value of which for the Upper Necropolis, 16.23 (tp=3254),[26] turned out to be distinctly higher from the value 9.24 (tp=552) for the Lower Necropolis. Moreover, this difference for a 95% confidence level, with χ^2=17.862 and p=2.375e-05, proved to be statistically significant. The difference between the sexes took the same direction and both were also statistically significant. For females of the earlier phase, it was 9.88 (tp=243), which in relation to the result 18.19 (tp=1501) for the Upper Necropolis gave χ^2=10.225 and p=0.001386 in the test of proportions. The results for males were 8.60 (tp=279) in the earlier phase and 14.97 (tp=1703) in the later phase, with χ^2=7.5278 and p=0.006075. The decided diachronic growth of the value of this index was dependent primarily on the considerably higher percentage of teeth lost during life, from 6.58% to 14.79% for females, from 5.73% to 11.45% for males, and from 5.80% to 12.81% for both sexes taken together.

More detailed analyses were undertaken to clarify this heterogeneous picture emerging from the summaries. A direct comparison of the proportion of teeth with carious changes to the total number available for study, considering particular tooth positions summarily for both sexes [***Table 26, Fig. 35***], revealed almost no differences between the two chronological phases. Although the frequencies for teeth Nos 2, 4, 5 and 6 lean more heavily in the direction of the Upper Necropolis, a reverse trend is observable in the case of Nos 3, 7 and 8. The picture becomes almost wholly homogeneous once the I-CE index is included, indicating increased number of changes connected with caries in the later phase of the cemetery [see ***Fig. 35***]. The exceptionally strong contrary trend in the case of the third molars (tooth position No. 8) is

[26] In keeping with the determinations in the table, tp is the number of so-called tooth positions (see *§ 3.3.8*).

Table 26. Frequency of carious lesions in individual teeth compared to healthy elements of the chewing apparatus, divided by cemetery phase; *n* – number of cases observed; *tp* – number of tooth positions; *il* – teeth lost intravitally; *pl* – teeth lost post mortem; *t* – teeth; *ct* – teeth with carious lesions; I_{CE} – index I-CE (index of caries *et extractio*)

		Lower Necropolis							
		1	2	3	4	5	6	7	8
tp		75	73	76	73	77	69	62	47
il	*n*	3	4	2	1	2	9	3	8
	%	4.00	5.48	2.63	1.37	2.60	13.04	4.84	17.02
pl	*n*	38	33	19	19	21	12	16	14
	%	50.67	45.21	25.00	26.03	27.27	17.39	25.81	29.79
t	*n*	34	36	55	53	54	48	43	25
	%	45.33	49.32	72.37	72.60	70.13	69.57	69.35	53.19
ct	*n*	0	0	2	3	3	4	4	3
	%	0.00	0.00	3.64	5.66	5.56	8.33	9.30	12.00
I_{CE}		**4.00**	**5.48**	**5.26**	**5.48**	**6.49**	**18.84**	**11.29**	**23.40**

		Upper Necropolis							
		1	2	3	4	5	6	7	8
tp		431	442	454	428	424	411	389	275
il	*n*	55	43	31	44	52	83	75	34
	%	12.76	9.73	6.83	10.28	12.26	20.19	19.28	12.36
pl	*n*	240	226	192	121	120	69	53	69
	%	55.68	51.13	42.29	28.27	28.30	16.79	13.62	25.09
t	*n*	136	173	231	263	252	259	261	172
	%	31.55	39.14	50.88	61.45	59.43	63.02	67.10	62.55
ct	*n*	0	4	6	20	19	27	22	13
	%	0.00	2.31	2.60	7.60	7.54	10.42	8.43	7.56
I_{CE}		**12.76**	**10.63**	**8.15**	**14.95**	**16.75**	**26.76**	**24.94**	**17.09**

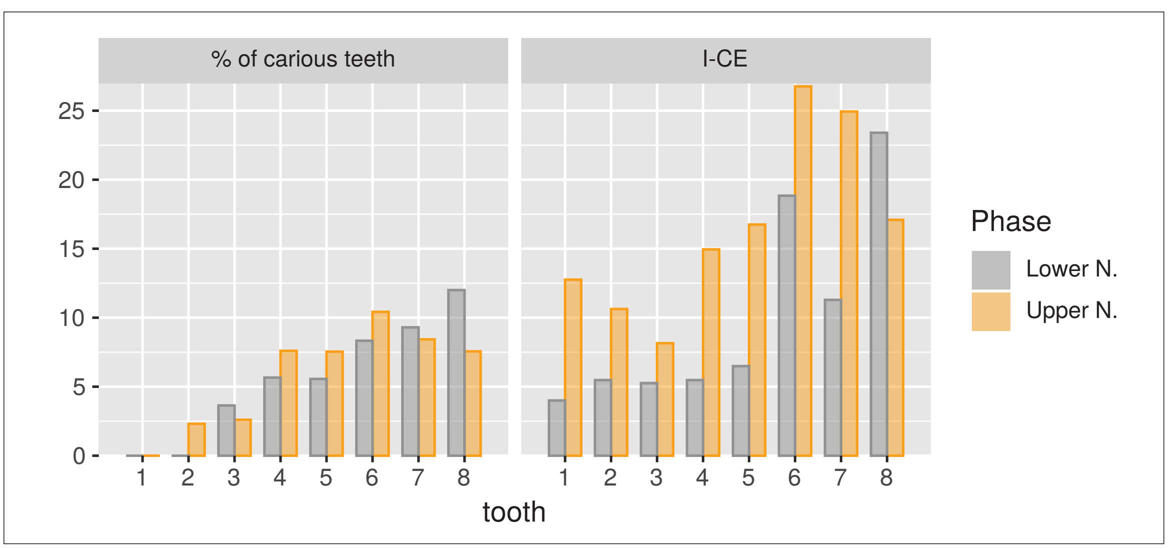

Fig. 35. Share of carious lesions in individual teeth compared to healthy elements of the chewing apparatus, divided by cemetery phase

surprising, demonstrating in the case of the Upper Necropolis clearly less carious lesions: 7.56% (*n*=172) compared to the 12.00% (*n*=25) for the Lower Necropolis. Coupled with the teeth lost ante mortem, respectively 12.36% (*tp*=275) and 17.02% (*tp*=47), this translated directly into the obtained values of the I-CE index, which reached levels of 17.09 and 23.40, respectively. However, none of the differences described here in the context of tooth No. 8 turned out to be statistically significant.

Examination of caries intensity revealed a similar but definitely more homogeneous distribution of changes [***Table 27, Fig. 36***]. Positions 2, 4, 5 and 6 on the graph for the scale not taking into account intravital tooth loss (scale 1–4) show a minimal deviation in favor of the Upper Necropolis, while positions 3, 7 and 8, show an equally minimal advantage of the Lower Necropolis. Interestingly, the summary intensity for both phases for this scale, unlike the frequency, turned out to be identical and amounted to 1.12. The same values considered by sex showed equally insignificant deviations. The total intensity of 1.14 for females [***Table 28***] on the four-grade scale indicates a minimally higher intensity of caries in the Lower Necropolis phase compared to the 1.11 obtained for the Upper Necropolis. The same value for males [***Table 29***], although going the opposite way, showed even less variation, 1.11 and 1.13 respectively. With such insignificant differences, if we take into account only preserved teeth, we see no changes in the intensity of caries between the cemetery phases. Neither were there any differences between the sexes that could be observed in this respect.

Taking into account also teeth lost ante mortem, an expected higher level of caries in the case of females, due to changes in the chemical environment of the oral cavity during pregnancy, more frequent food intake in connection with meal preparation or earlier teething (Lorkiewicz 2012: 121; Lukacs and Largaespada 2006: 540),[27] is observed for almost all tooth types from both phases of the cemetery [***Tables 28, 29, Figs 37, 38***]. Teeth Nos 6 and 8 for the Lower Necropolis and No. 7 for the Upper Necropolis turned out to be exceptions, but the intensity calculated for all teeth together, separately for each sex, confirms the observed relationships. A summary comparison for the five-grade scale, not taking into account the sex of the deceased, and thus including also individuals without established sex, reveals a similar picture [see ***Table 27, Fig. 36***]. It clearly shows an increase in the intensity of caries in the Upper Necropolis phase, compared to the situation observed in the Lower Necropolis phase. The value of this feature for all tooth positions counted together was 1.89 and 1.49, respectively, but only for position 8 this relation turned out to be reversed, giving 1.76 and 2.09.

The picture that emerges from the above considerations seems, despite some inconsistencies, to indicate a clear diachronic increase of changes generally associated with tooth caries. They were more frequent and more intense in burials of the Upper Necropolis compared to those of the Lower Necropolis. While both the percentage and intensity of caries in teeth were almost identical for both phases under consideration, and taking into account the relevant situation for individual types of teeth, the observed difference was determined by the teeth lost in life. If, following Caselitz, we assume that the bulk of intravital loss of teeth was caused by caries and the teeth lost post mortem were healthy (Caselitz 1998: 205), the increase in the number and intensity of such

[27] Reverse relations were also recorded at other sites. They were explained primarily by the greater average life expectancy of men in the populations studied (Slaus 2000: 198–199).

Table 27. Intensity of carious lesions in the teeth of individuals buried in the Kom el-Dikka cemetery, divided by cemetery phase; *Score x* – number of teeth with carious lesions of degree *x*; *n* – number of tooth positions for a five-grade scale; *ic* – intensity of caries for a five-grade scale; n_{1-4} – number of tooth positions on a four-grade scale; ic_{1-4} – intensity of caries on a four-grade scale; data for successive eight teeth (regardless of quadrant) presented in columns

	Lower Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	30	30	44	43	44	39	35	21	286
Score 2	0	0	0	1	0	3	2	3	9
Score 3	0	0	0	0	1	0	0	0	1
Score 4	0	0	2	2	2	1	2	0	9
Score 5	3	4	2	1	2	9	3	8	32
n	33	34	48	47	49	52	42	32	337
ic	1.36	1.47	1.29	1.23	1.33	1.81	1.48	2.09	1.49
n_{1-4}	30	30	46	46	47	43	39	24	305
ic_{1-4}	1.00	1.00	1.13	1.15	1.17	1.14	1.21	1.12	1.12

	Upper Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	129	161	223	230	224	224	238	155	1584
Score 2	0	2	1	8	6	16	12	9	54
Score 3	0	1	2	2	2	7	6	3	23
Score 4	0	1	3	10	11	4	4	1	34
Score 5	55	43	31	44	52	83	75	34	417
n	184	208	260	294	295	334	335	202	2112
ic	2.20	1.86	1.53	1.74	1.85	2.12	2.00	1.76	1.89
n_{1-4}	129	165	229	250	243	251	260	168	1695
ic_{1-4}	1.00	1.04	1.06	1.17	1.18	1.17	1.14	1.11	1.12

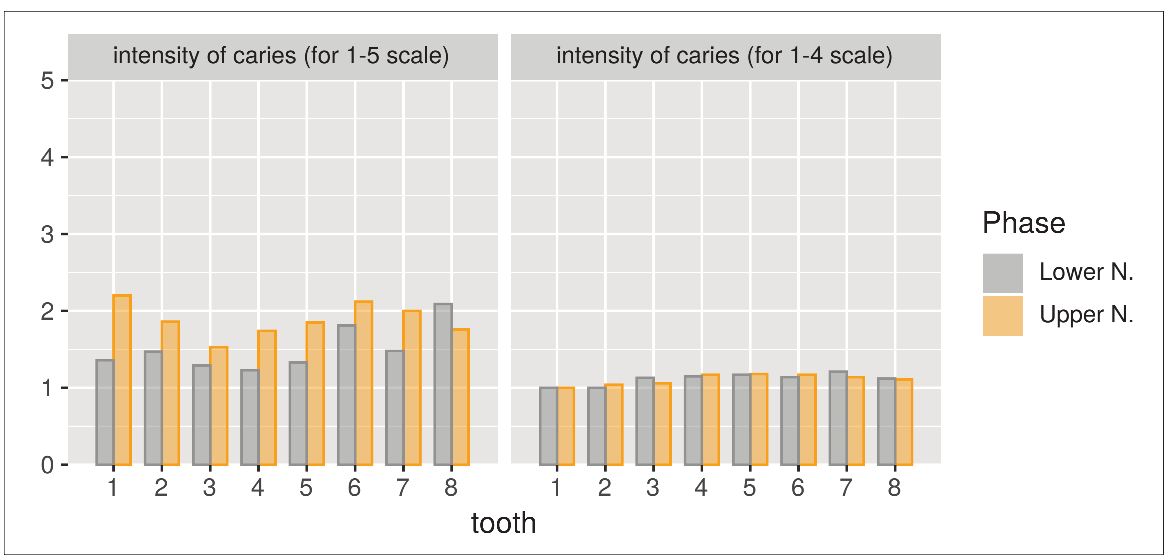

Fig. 36. Intensity of caries in the teeth of individuals buried in the Kom el-Dikka cemetery, divided by cemetery phase

Table 28. Intensity of carious lesions in the teeth of females buried in the Kom el-Dikka cemetery, divided by cemetery phase; *Score x* – number of teeth with carious lesions of degree *x*; *n* – number of tooth positions for a five-grade scale; *ic* – intensity of caries for a five-grade scale; n_{1-4} – number of tooth positions for a four-grade scale; ic_{1-4} – intensity of caries for a four-grade scale; data for successive eight teeth (regardless of quadrant) presented in columns

	Lower Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	10	13	19	19	22	19	13	9	124
Score 2	0	0	0	1	0	1	0	1	3
Score 3	0	0	0	0	0	0	0	0	0
Score 4	0	0	1	1	1	0	2	0	5
Score 5	3	3	2	1	2	2	1	2	16
n	13	16	22	22	25	22	16	12	148
ic	1.92	1.75	1.50	1.36	1.44	1.41	1.62	1.75	1.55
n_{1-4}	10	13	20	21	23	20	15	10	132
ic_{1-4}	1.00	1.00	1.15	1.19	1.13	1.05	1.40	1.10	1.14

	Upper Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	65	77	106	104	96	97	111	67	723
Score 2	0	0	0	4	3	8	7	6	28
Score 3	0	1	0	1	2	2	2	1	9
Score 4	0	0	0	4	6	2	2	0	14
Score 5	34	24	18	25	28	41	33	19	222
n	99	102	124	138	135	150	155	93	996
ic	2.37	1.96	1.58	1.86	2.01	2.21	1.96	1.90	1.98
n_{1-4}	65	78	106	113	107	109	122	74	774
ic_{1-4}	1.00	1.03	1.00	1.16	1.23	1.17	1.14	1.11	1.11

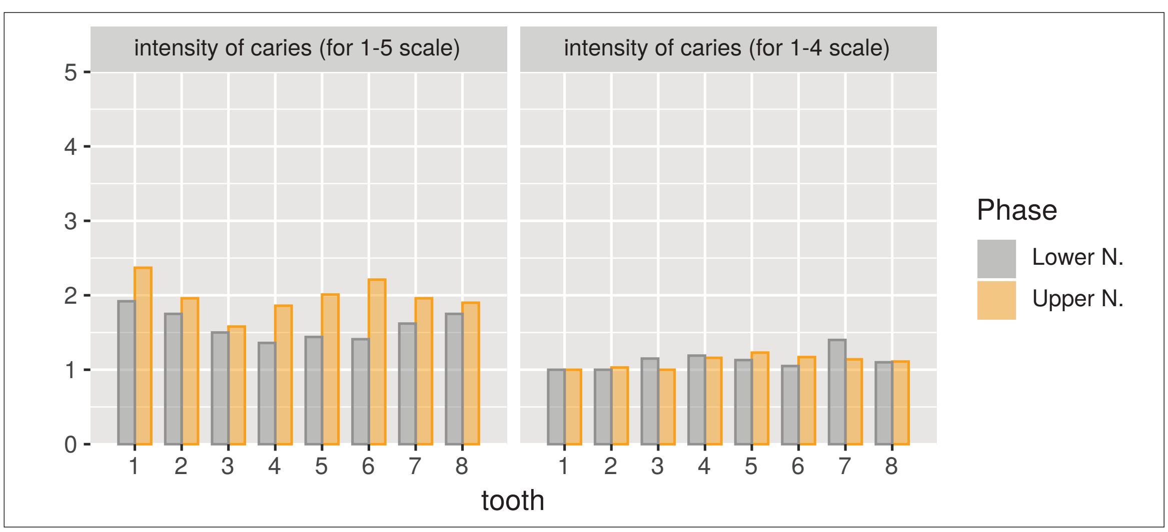

Fig. 37. Intensity of caries in teeth of females buried in the Kom el-Dikka cemetery, divided by cemetery phase

Table 29. Intensity of carious lesions in the teeth of males buried in the Kom el-Dikka cemetery, divided by cemetery phase; *Score x* – number of teeth with carious lesions of degree *x*; *n* – number of tooth positions for a five-grade scale; *ic* – intensity of caries for a five-grade scale; n_{1-4} – number of tooth positions for a four-grade scale; ic_{1-4} – intensity of caries for a four-grade scale; data for successive eight teeth (regardless of quadrant) presented in columns

	Lower Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	18	14	22	20	19	18	20	8	139
Score 2	0	0	0	0	0	1	1	2	4
Score 3	0	0	0	0	0	0	0	0	0
Score 4	0	0	1	1	1	1	0	0	4
Score 5	0	1	0	0	0	7	2	6	16
n	18	15	23	21	20	27	23	16	163
ic	1.00	1.27	1.13	1.14	1.15	2.19	1.39	2.62	1.49
n_{1-4}	18	14	23	21	20	20	21	10	147
ic_{1-4}	1.00	1.00	1.13	1.14	1.15	1.20	1.05	1.20	1.11

	Upper Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	64	83	115	122	122	122	122	85	835
Score 2	0	2	1	4	3	8	5	3	26
Score 3	0	0	2	1	0	5	4	2	14
Score 4	0	1	3	6	5	2	2	1	20
Score 5	21	19	13	19	24	42	42	15	195
n	85	105	134	152	154	179	175	106	1090
ic	1.99	1.77	1.49	1.66	1.74	2.07	2.07	1.66	1.82
n_{1-4}	64	86	121	133	130	137	133	91	895
ic_{1-4}	1.00	1.06	1.12	1.18	1.14	1.18	1.14	1.11	1.13

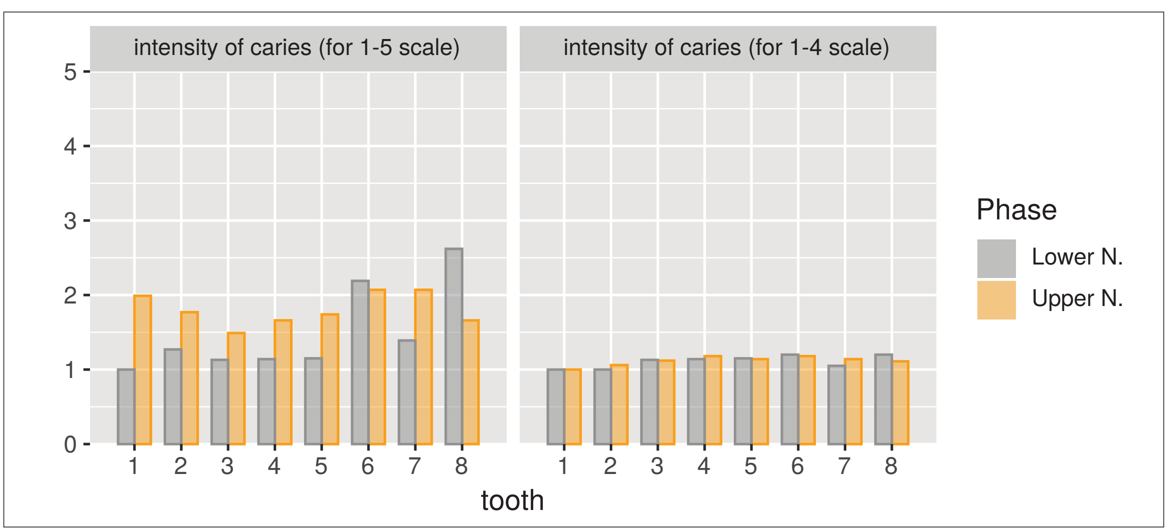

Fig. 38. Intensity of caries in teeth of males buried in the Kom el-Dikka cemetery, divided by cemetery phase

changes in the studied skeletal population from the Upper Necropolis seems undeniable. A closer look at dental wear, one of the two most frequent causes of tooth loss apart from caries (Duyar and Erdal 2003: 58), may either support or challenge this observation.

Dental crown wear, if not caused by pathological changes, is the result of long-term attrition and abrasion of the teeth caused by tooth-on-tooth friction and by food of different kinds and composition, particularly by abrasive factors present in food, possibly also by using teeth as tools. Its degree is usually negatively correlated with carious lesions. The two cemetery phases reveal practically no differences in this respect [***Table 30, Fig. 39***]. It follows that this factor, only slightly higher in the case of the Upper Necropolis—summarily 3.41 compared to 3.37 in the case of the Lower Necropolis—must have affected the formation of caries equally in both chronological series, so it would not have influenced the results of the comparisons between phases discussed above.

A detailed explanation is in order here. Caries frequencies were not analyzed in the context of the age-at-death of the deceased due to the limited sample, especially in the case of the Lower Necropolis. However, the degree of wear could be a good estimate of age-at-death profiles directly connected with the analyzed odontological material, being dependent on abrasive factors in food and the passage of time (White 2000: 344). One could assume that the average presence of abrasive factors in the food of the people burying their dead on Kom el-Dikka did not change substantially over the ages covered by this research. The use of teeth as tools was noted with regard to just a few individuals from the cemetery, but the occlusal surfaces were either not used in these cases or the degree of wear involved was not marked enough to be detected. Therefore, assuming the truth of the premises, the absence of differences in the pattern of teeth wear from the two phases indicates a close similarity of age-at-death profiles of the teeth attributed to them. By the same, the age-at-death of the deceased most likely had no effect on changes in the frequency and intensity of caries observed in the transition from the earlier to the later phase of the cemetery. Thus, the higher frequency of ante mortem tooth loss observed for the later phase may be attributed to a situation of more advanced caries among the deceased in this phase.

More carbohydrates in the diet, especially sugar, also in the form of honey, or sweet fruits such as dates, could be a reason for such directed change (Lanfranco and Eggers 2012: 15). Less meat and fish in the food and more meals during the day could have also been part of the reason, as also the number of children born to individual women (Lanfranco and Eggers 2012: 17–19).[28] Thus, it usually involves a change in the wellbeing of a population, although it is difficult to judge the direction of these changes on the basis of decay itself. In general, however, rising standards of living tend to be accompanied by a growing frequency of tooth decay (Caselitz 1998: 209).

3.4.4.2 *Enamel hypoplasia*

While dental enamel hypoplasia is not dependent on age, when observed in adults, it is a manifestation of physiological stress at the time of crown formation (Goodman and Martin 2002: 24; Goodman and Rose 1991: 284; Larsen 1997: 44–46) and as such should characterize primarily

[28] Hormonal fluctuations during puberty, menstruation, and pregnancy are the reasons for more cariogenic saliva composition (Lanfranco and Eggers 2012: 19).

Table 30. Degree of wear of the teeth of individuals buried in the Kom el-Dikka cemetery, divided by cemetery phase; *Score x* – number of teeth with wear of degree *x*; *n* – number of teeth; *iw* – intensity of wear; data for successive eight teeth (regardless of quadrant) presented in columns

	Lower Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	4	7	10	7	5	6	5	4	48
Score 2	7	5	7	4	4	0	0	4	31
Score 3	3	2	8	9	10	9	17	10	68
Score 4	11	11	13	11	11	19	9	1	86
Score 5	5	3	6	5	7	3	4	4	37
Score 6	0	2	2	8	8	4	0	0	24
Score 7	0	0	0	0	0	1	0	0	1
n	30	30	46	44	45	42	35	23	295
iw	3.20	3.13	3.09	3.61	3.78	3.69	3.20	2.87	3.37

	Upper Necropolis								Σ
	1	2	3	4	5	6	7	8	
Score 1	10	16	29	18	17	12	11	20	133
Score 2	8	45	37	26	20	8	23	18	185
Score 3	18	19	12	47	42	54	84	44	320
Score 4	62	41	90	39	35	98	77	43	485
Score 5	6	6	11	51	62	24	9	8	177
Score 6	2	5	7	15	12	7	6	3	57
Score 7	0	0	0	0	0	0	0	0	0
n	106	132	186	196	188	203	210	136	1357
iw	3.49	2.93	3.20	3.63	3.75	3.67	3.32	3.07	3.41

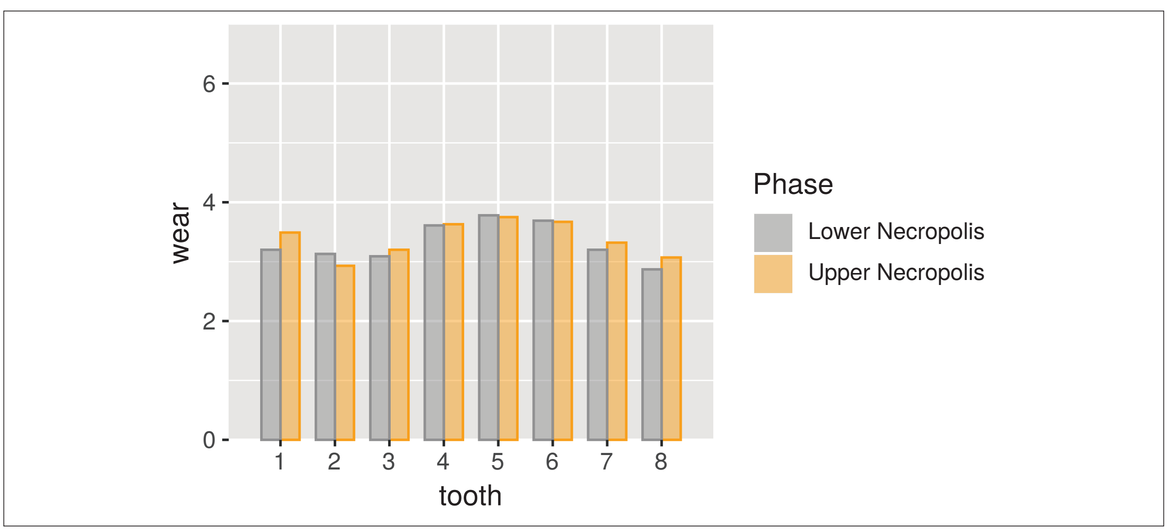

Fig. 39. Degree of wear of the teeth of individuals buried in the Kom el-Dikka cemetery, divided by cemetery phase

weaker individuals with a lesser chance to live to maturity. A comparison of the percentage of adolescents and adults with changes of this kind revealed no major differences between the two groups, hence the decision to analyze the data for all age groups jointly. Even so, the sample was too small, especially with regard to the Lower Necropolis, to be able to treat separately severe cases, with a score 3 in the catalog in Appendix B. Consequently, single teeth or rather tooth positions were analyzed solely in the context of the number of individuals for whom these observations could be made [***Table 31***][29] and divided into three functional groups: incisors, canines, and the rest of the teeth (premolars and molars) together. The data were also summarized for all types together. The results were not explicit [***Fig. 40***]. The percentage of individuals with hypoplastic changes of the enamel (positions 1–8) noted for the Upper Necropolis, 54.97% (n=171), demonstrated a slight drop compared to the earlier phase, 58.62% (n=29), χ^2=0.13375 and p=0.7146. The direction of changes for females was basically in agreement with the results, respectively, 48.05% (n=77) and 53.85% (n =13) (χ^2=0.14944 and p=0.6991), but was converse for males, amounting to 65.00% (n=80) and 60% (n=15) (χ^2=0.13742) and p=0.7109). However, none of these differences reaching five percentage points, taking into account the sex of the deceased, proved statistically significant for the assumed 95% confidence level.

In turn, the differences between the sexes took on a decided direction for both phases with over six percentage points superiority of males with such changes in the earlier phase (60.00% for males and 53.85% for females) and growing to over 17 percentage points in the later phase (65.00% for males and 48.05% for females). For the earlier phase the difference was, understandably due to the small sample, statistically insignificant (χ^2=0.10769 and p=0.7428), but at χ^2=4.5901 and p=0.03216, it was confirmed by the test for the Upper Necropolis.

The observed relations become even more complicated for dental hypoplasia considered from the point of view of the functional groups that the teeth were divided into. The diachronic drop from phase to phase for the incisors is 7.49 percentage points from 52.94% (n=17) to 45.45% (n=88), for canines instead the rise is clear, by 9.46 percentage points from 50.00% (n=22) to 59.46% (n=111), and a visibly lesser rise for the joint group of premolars and molars, that is, 3.96 percentage points from 27.59% (n=29) to 31.55% (n=168). The trends for males alone are similar: a distinct drop in the percentage of male individuals with such changes in the incisors group, by 11.28 percentage points from 62.50% (n=8) to 51.22% (n =41), and two successive rises, relatively very high for the canines, amounting to 27.10 percentage points from 36.6% (n=11) to 63.46% (n=52), and a much gentler one for the premolars and molars, 11.79 percentage points from 26.67% (n=15) to 38.46% (n=78). For the females, however, the changes presented an opposite turn with a small rise for the incisors by 6.09 percentage points from 37.50% (n=8) to 43.59% (n=39), and slight drops for canines, by 3.14 percentage points from 60.00% (n=10) to 56.86% (n=51), and for the premolar and molar group, by 4.45 percentage points from 30.77% (n=13) to 26.32% (n=76).

None of the observed differences in the proportion of individuals with and without dental enamel hypoplasia proved statistically significant at the assumed 95% level of confidence, both

[29] Singular teeth with linear enamel hypoplasia were used as a fully-fledged indicator of this condition. It was not possible to take into account only the changes that could be observed on the same tooth positions symmetrically within the same maxilla or mandibula due to the poor state of the preservation of the material.

Table 31. Individuals with hypoplastic changes of dental enamel (LEH) divided by sex and cemetery phase. Calculations separately for incisors (teeth 1–2), canines (tooth 3), premolars and molars together (teeth 4–8) and summarily for all types together (teeth 1–8); n – number of individuals for whom no less than one tooth from a group could be examined; n_{hi} – number of individuals with enamel hypoplasia on at least one tooth from a group; % – percentage share of individuals with enamel hypoplasia

		Teeth 1–2			Tooth 3			Teeth 4–8			Teeth 1–8		
	Sex	n	n_{hi}	%	n	n_{hi}	%	n	n_{hi}	%	n	n_{hi}	%
Lower Necropolis	♀	8	3	37.50	10	6	60.00	13	4	30.77	13	7	53.85
	♂	8	5	62.50	11	4	36.36	15	4	26.67	15	9	60.00
	?	1	1	100.00	1	1	100.00	1	0	0.00	1	1	100.00
	Σ	17	9	52.94	22	11	50.00	29	8	27.59	29	17	58.62
Upper Necropolis	♀	39	17	43.59	51	29	56.86	76	20	26.32	77	37	48.05
	♂	41	21	51.22	52	33	63.46	78	30	38.46	80	52	65.00
	?	8	2	25.00	8	4	50.00	14	3	21.43	14	5	35.71
	Σ	88	40	45.45	111	66	59.46	168	53	31.55	171	94	54.97
?	♀	1	1	100.00	1	1	100.00	1	1	100.00	1	1	100.00
	♂	2	1	50.00	1	0	0.00	2	2	100.00	2	2	100.00
	?	0	0	–	0	0	–	0	0	–	0	0	–
	Σ	3	2	66.67	2	1	50.00	3	3	100.00	3	3	100.00
Σ	♀	48	21	43.75	62	36	58.06	90	25	27.78	91	45	49.45
	♂	51	27	52.94	64	37	57.81	95	36	37.89	97	63	64.95
	?	9	3	33.33	9	5	55.56	15	3	20.00	15	6	40.00
	Σ	108	51	47.22	135	78	57.78	200	64	32.00	203	114	56.16

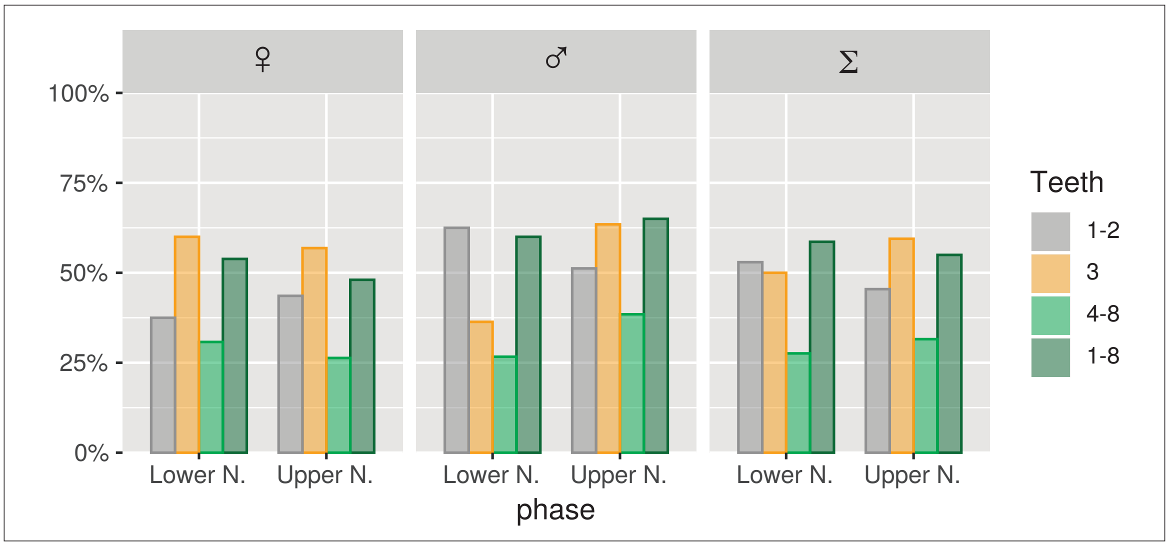

Fig. 40. Individuals with dental hypoplasia divided by sex and cemetery phase. Visualization separately for incisors (positions 1–2), canines (position 3), premolars and molars together (positions 4–8) and summarily for all types together (teeth 1–8)

for the analyses between chronological phases and between the sexes within a single phase. This was due most probably to the small sample, reaching an extreme in the case of the Lower Necropolis, thus demonstrating the need for extra caution when interpreting the observed regularities.

The results point to a slight drop in the percentage of individuals with dental hypoplasia in the Upper Necropolis phase, suggesting a slight general improvement of living conditions for the youngest (Goodman and Martin 2002: 25–26). The slight growth among men in this context is worth noting, considering that boys are more likely than girls to react to environmental stressors (Lorkiewicz 2012: 139) and could have subsequently been more sensitive to weaning as babies, which is traditionally blamed for the appearance of dental hypoplasia (Goodman and Rose 1991: 286; Lewis 2007: 106). While some researchers consider this as circumstantial (Larsen 1997: 49), there is full agreement that dental hypoplasia is the result of physiological stress and weaning is one of the strongest in this respect in view of the fundamental change in the kind of food given to a baby.

The only statistical difference, as described above, was in the frequency of dental hypoplasia on permanent teeth of males and females. The observed gap, growing between the sexes in the Upper Necropolis phase, suggests a change that might have led over time to a selective worsening of living conditions for male children. An opposite conclusion can be reached based on the same source base and taking into account the osteological paradox raised by James W. Wood and others (1992). Since there is no data on the youngest children in the analyzed set, then we are dealing with a frequency calculated for a group of individuals with changes who outgrew the period of stress, of which it is a reflection. Hence, the higher percentage of boys compared to girls with these changes could be evidence of their better situation, since they had survived the worst. Therefore, it is probable, considering the differences observed between the Lower and Upper phases, that their situation was improving over time, both in absolute terms and in relation to their female peers.

Taking into account the order in which the crowns of permanent teeth are formed and the time span over which this process takes place, which is also when the enamel defects form on different teeth in the process of ontogenesis (Goodman and Rose 1991: Fig. 3), it may be said in general that incisors are formed first, followed by canines and, last, by premolars and molars. The age brackets assigned to this process overlap extensively. Based on the distribution of frequencies of dental hypoplasia on different teeth (Lorkiewicz 2012: 142–143), such changes observed on canines should, on average, appear later in the ontogenesis than those appearing on incisors. Analogously, considering the formation sequence and the relations mentioned in the context of the incisors and canines, it may be surmised that the average age when these changes are formed on premolars and molars is even higher.

Therefore, the diachronic pattern of changes for girls demonstrates a slightly higher percentage of dental hypoplasia in the earliest stages of life and an equally low drop in early childhood. The trend for boys was much more distinct and reversed: a lesser percentage of changes at the youngest stage corresponding to a higher percentage in the later stages of childhood. The regularities, which are not statistically significant, could be explained by several different factors, none of which are supported by believable premises. The picture that emerges here, however, is of a slight drop in the average age at which physiological stress would cause dental hypoplasia in girls and its clear shift to a later stage in th ontogenesis in the case of boys, as seen in the context of the transition from the Lower to the Upper Necropolis.

3.4.5 *Cribra orbitalia*

Cribra orbitalia, porosity of the orbital roof, forms due to red marrow expansion when in need of higher blood cell production (Larsen 1997: 32). It is the only skeletal pathology to be taken into account in this work (for the methodological premises see *§ 3.3.9*). As a non-specific indicator of physiological stress, primarily in childhood (Lorkiewicz 2012: 131), of a different etiology than in the case of enamel hypoplasia, *cribra orbitalia* describes a different kind of stress affecting individuals (Kozak and Krenz-Niedbała 2002: 80). The condition was assessed for 59 individuals buried in the Lower Necropolis: 17 children and 42 adults [*Table 33*]. The series for the Upper Necropolis, counting 190 individuals, so almost four times as many, was composed of 36 children (under 20) and 154 adults.

The percentage of skeletons with *cribra orbitalia* when considering the whole sample [***Fig. 41***] shows no diachronic change in this respect, under the condition that it is counted summarily without taking into consideration sex, age or degree of expression of the pathology. The result was 30.51% (n=59) for the Lower Necropolis and 30.53% (n=190) for the Upper Necropolis. If the sex of the buried individuals is taken into consideration, the emerging picture is no longer equally homogeneous. The percentage for women between phases is almost doubled, from 14.29% (n=21) to 28.57% (n=77). For individuals of undetermined sex, the rise is perhaps not so substantial—7.14 percentage points, from 42.86% (n=14) to 50.00% (n=34)—but for men there is a clear drop by 13.45 percentage points, from 37.50% (n=24) to 24.05% (n=79). None of these differences, however, were statistically significant.

The results of proportion tests, at a confidence level of 95%, proved equally insignificant statistically for severe changes of this kind. The trends were identical with those observed earlier, but the change in frequency was much gentler in this case, while the sum grew slightly by 2.06 percentage

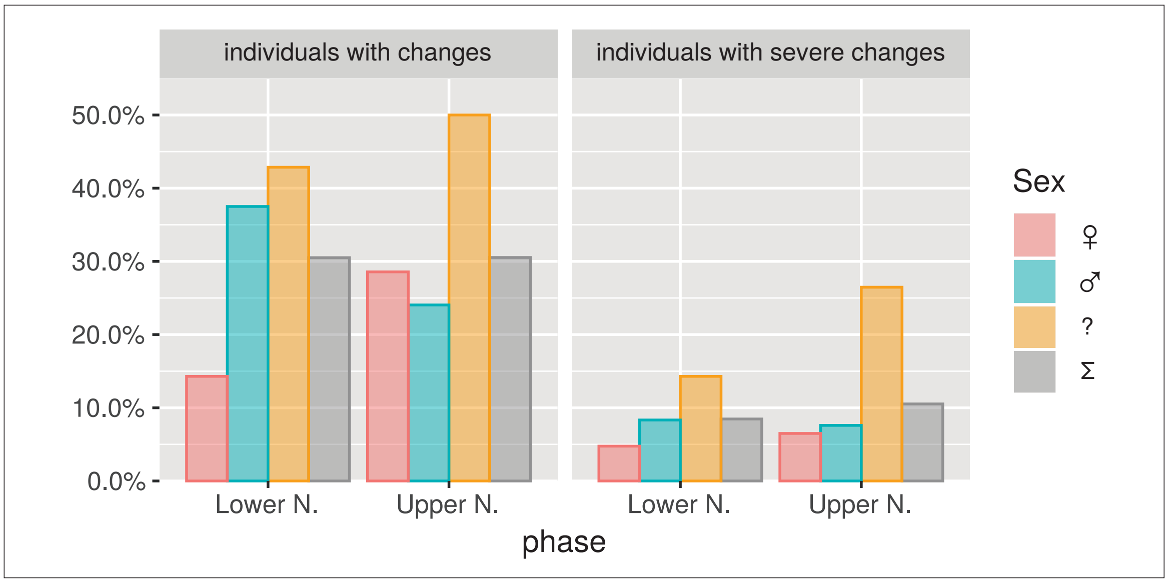

Fig. 41. Percentage of individuals with *cribra orbitalia* changes, divided by sex and cemetery phase

points, from 8.47% (n=59) to 10.53% (n=190). A slight rise was noted for females, by 1.73 percentage points, from 4.76% (n=21) to 6.49% (n=77), and almost double the sum for individuals of unidentified sex, 12.18 percentage points, from 14.29% (n=14) to 26.47% (n=34). A minimal drop was noted for males, 0.74 percentage points, from 8.33% (n=24) to 7.59% (n=79).

Taking again into consideration all the *cribra orbitalia* changes during the transition from the earlier to the later phase, mutual relations between the sexes appear to have changed. For the earlier phase, it was statistically insignificant, but still a sizable 23.21 percentage points difference, 14.29% for females and 37.50% for males. For the later phase, it dropped to 4.52 percentage points and changed direction, reaching a respective 28.57% for females and 24.05% for males.

The only statistically significant difference at the assumed confidence level of 95% was between the percentage of changes in both sexes and the result for skeletons of unidentified sex, summarily counting children and adults. In addition, most likely because of the size of the series, this was true only for the Upper Necropolis. With an outcome of 50.00% (n=34) for individuals of unknown sex, the difference for females, 28.57% (n=77), reached 21.43 percentage points with χ^2=4.7521 and p=0.02926, and for males, 24.05% (n=79), 25.95 percentage points, with χ^2=7.373 and p=0.006621. The Lower Necropolis had 42.86% (n=14) individuals of unknown sex, whereas the respective differences were 28.57 percentage points for females, 14.29% (n=21), with χ^2=2.2498 and p=0.1336, and only 5.36 percentage points for males, 37.50% (n=24), with χ^2=0.28642 and p=0.5925.[30]

Children constituted, chiefly although not exclusively, the group of individuals without identified sex in this comparison [***Table 33***]. In the case of men and women, not all the skeletons of identified sex could be included in the adult group. Differences in the percentage share of

[30] In the χ^2 test of proportions, Yates' correction was introduced if the number within a group considered for calculation was less than 5 (Howell 2012: 147; Wikipedia 2020b). This substantially raised the obtained p value, considerably lowering the chances for a statistical significance of the examined differences.

Table 32. Number of cases of *cribra orbitalia* among children, divided by degree of changes, taking into account age-at-death brackets and cemetery phase; n – number of individuals with orbital roof(s) examined; n_{co} – number of individuals with changes; n_{sco} – number of individuals with severe changes (score 3); % – percentage of individuals with changes (or severe changes)

	Cribra orbitalia											
	0–7 yrs			**7–14 yrs**			**14–20 yrs**			**Σ**		
	n	n_{co}	%	n	n_{co}	%	n	n_{co}	%	n	n_{co}	%
Lower Necropolis	6	0	0.00	6	5	83.33	4	3	75.00	17	8	47.06
Upper Necropolis	20	10	50.00	4	3	75.00	11	6	54.55	36	19	52.78
?	1	1	100.00	0	0	–	0	0	–	1	1	100.00
Σ	27	11	40.74	10	8	80.00	15	9	60.00	54	28	51.85

	Cribra orbitalia (score 3)											
	0–7 yrs			**7–14 yrs**			**14–20 yrs**			**Σ**		
	n	n_{sco}	%	n	n_{sco}	%	n	n_{sco}	%	n	n_{sco}	%
Lower Necropolis	6	0	0.00	6	2	33.33	4	1	25.00	17	3	17.65
Upper Necropolis	20	6	30.00	4	2	50.00	11	2	18.18	36	10	27.78
?	1	0	0.00	0	0	–	0	0	–	1	0	0.00
Σ	27	6	22.22	10	4	40.00	15	3	20.00	54	13	24.07

Table 33. Number of cases of *cribra orbitalia* divided by adults and children, taking into consideration sex, degree of changes, and cemetery phase; n – number of individuals with orbital roof(s) examined; n_{co} – number of individuals with changes; n_{sco} – number of individuals with severe changes (score 3); % – percentage of individuals with changes (or with severe changes)

		Children (0–20 yrs)					Adults (20–x yrs)					Σ				
	Sex	n	n_{co}	%	n_{sco}	%	n	n_{co}	%	n_{sco}	%	n	n_{co}	%	n_{sco}	%
Lower Necropolis	♀	1	0	0.00	0	0.00	20	3	15.00	1	5.00	21	3	14.29	1	4.76
	♂	2	2	100.00	1	50.00	22	7	31.82	1	4.55	24	9	37.50	2	8.33
	?	14	6	42.86	2	14.29	0	0	–	0	–	14	6	42.86	2	14.29
	Σ	17	8	47.06	3	17.65	42	10	23.81	2	4.76	59	18	30.51	5	8.47
Upper Necropolis	♀	2	1	50.00	0	0.00	75	21	28.00	5	6.67	77	22	28.57	5	6.49
	♂	3	2	66.67	1	33.33	76	17	22.37	5	6.58	79	19	24.05	6	7.59
	?	31	16	51.61	9	29.03	3	1	33.33	0	0.00	34	17	50.00	9	26.47
	Σ	36	19	52.78	10	27.78	154	39	25.32	10	6.49	190	58	30.53	20	10.53
?	♀	0	0	–	0	–	1	1	100.00	0	0.00	1	1	100.00	0	0.00
	♂	0	0	–	0	–	1	0	0.00	0	0.00	1	0	0.00	0	0.00
	?	1	1	100.00	0	0.00	2	1	50.00	1	50.00	3	2	66.67	1	33.33
	Σ	1	1	100.00	0	0.00	4	2	50.00	1	25.00	5	3	60.00	1	20.00
Σ	♀	3	1	33.33	0	0.00	96	25	26.04	6	6.25	99	26	26.26	6	6.06
	♂	5	4	80.00	2	40.00	99	24	24.24	6	6.06	104	28	26.92	8	7.69
	?	46	23	50.00	11	23.91	5	2	40.00	1	20.00	51	25	49.02	12	23.53
	Σ	54	28	51.85	13	24.07	200	51	25.50	13	6.50	254	79	31.10	26	10.24

individuals exhibiting the change indicate almost twice as big a percentage in the children's group (0–20 years) compared to that of the adults. Also noticeable is the slight rise over time in both groups [***Fig. 42***]. For the Lower Necropolis, the difference was statistically insignificant at χ^2=3.0854 and p=0.079, and amounted to 23.25 percentage points, 47.06% with changes in the group of younger age (n=17) and 23.81% in the adult group (n=42). The difference for the Upper Necropolis reached 27.46 percentage points, respectively 52.78% (n=36) and 25.32% (n=154), turning out to be statistically significant owing to the relatively numerous series for this phase, with χ^2=10.369 and p=0.0013. It follows that, beside a clear relation between the frequency of the change and the age of the individuals, the absence of diachronic change seen before for the whole series was the effect of differences in age composition. The results demonstrate a slight rise in the percentage of individuals with *cribra orbitalia* in the children's group from the Upper Necropolis compared to the situation observed for the Lower Necropolis. A similar picture ensued from a comparison of analogous frequencies of severe changes (score 3) and although statistical tests for such small groups are useless [***Table 33***], it was also possible to observe a slight rise in the observed proportions over time.

Looking at the distribution in the children's group alone [***Fig. 43***], one can assume that the discussed increase was caused by the change in the youngest child group (0–7 years). It is true that the small sample greatly handicaps the conclusions [see ***Table 32***], but the complete absence of individuals with *cribra orbitalia* in the 0–7 year group, 0% (n=6), from the Lower Necropolis material is surprising considering that the percentage for the Upper Necropolis is 50% (n=20). In the other two age brackets for children, there was a relative drop: slight for the 7–14 years group, by 8.33 percentage points, from 83.33% (n=6) to 75.00% (n=4), and much bigger, by 20.45 percentage points, from 75.00% (n=4) to 54.55% (n=11) for the 14–20 years group. In the case of severe changes (score 3), there was a rise in the proportions over time in the first two age groups and then a slight drop in the third group (14–20 years).

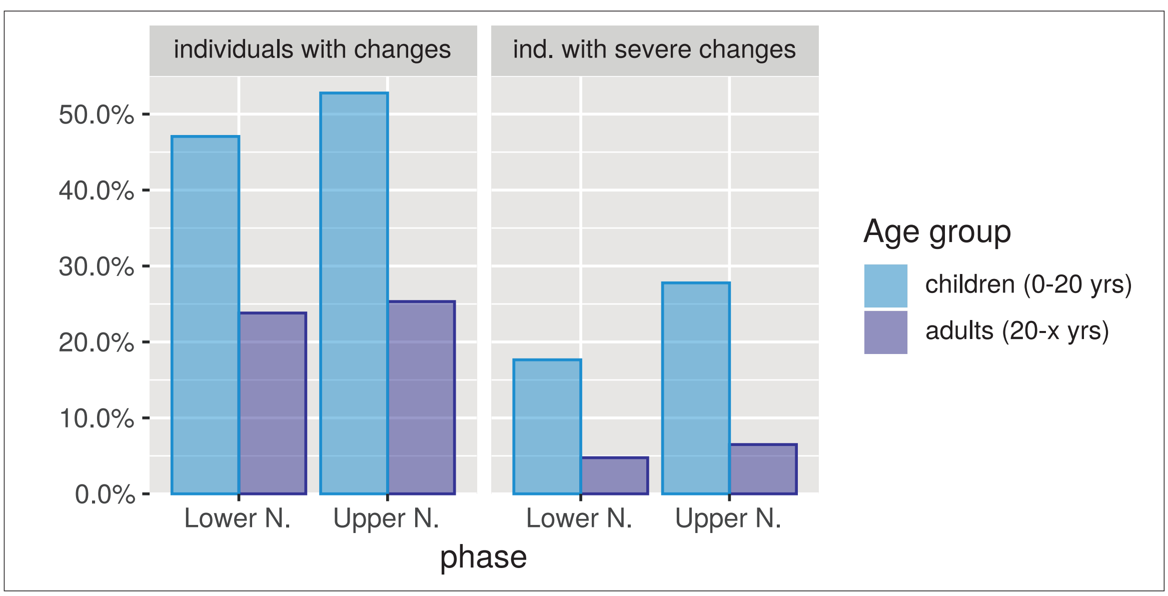

Fig. 42. Percentage of individuals with *cribra orbitalia* changes, divided by age-at-death brackets and cemetery phase

The frequency distribution of *cribra orbitalia* in adults [see ***Table 34, Fig. 44***] reveals a percentage rise in mature females, doubled almost, from 19.35% (n=31) in young age (20–35 years), to 37.50% (n=32) in maturity (35–55 years), buried in the Upper Necropolis. The one from the Lower Necropolis, rising from 12.50% (n=8) to 20.00% (n=10), was definitely weaker. The trend for males was the opposite, two times less in the Lower Necropolis, from 50.00% (n=8) to 23.08% (n=13), and even stronger in the case of the Upper Necropolis, from 34.48% (n=29) to 13.16% (n=38). Only the lattermost difference, with an assumed 95% confidence level, turned out to be statistically significant (χ^2=4.3046 and p=0.03801). The small size of the samples in the observed groups was responsible most probably for insignificance of the differences when tested. Women (n=2) and men (n=1) of elderly age (55 and more) from the Lower Necropolis phase were not included in the analyses due to the extremely unrepresentative character of the series for this age-at-death bracket.

Formation of *cribra orbitalia* and its picture is dependent on a series of genetic and environmental factors, such as anemia, as well as infections and malnutrition. It forms in response to physiological stress primarily in childhood, because red marrow in this part of life takes up all of the space available (Larsen 1997: 32), and the thin plate of the orbital roof is more susceptible to porotic hyperostosis (Wapler et al. 2004: 338). In this context, the observed significantly higher percentage of *cribra orbitalia* among children buried in the Kom el-Dikka cemetery is not surprising, while the distinct change in the relations between the sexes may be interpreted, at least in part, as a reflection of what took place already among the youngest. Generally in the archaeological material, changes of this type occur most often in children under five years old (Larsen 1997: 32). With regard to the Kom el-Dikka burials, the apogee seems to have concerned individuals in later childhood (7–14 years), not the very young, but for the most part most probably before or on the verge of puberty [***Fig. 43***]. The sudden jump among the youngest (0–7 years) in the Upper Necropolis phase merits note.

Leaving aside a discussion of the causes of porotic hyperostosis, the observed changes can be explained in their entirety by population shifts due to migration processes. It could have also been the outcome of changes in the social structure of contemporary Alexandria, that is, changes caused by the Arabization and Islamization of a population with a different base that joined the ranks of the population burying its dead on Kom el-Dikka. However, no evaluation of the possible diachronic changes in the genetic background could be made in view of the small dataset from the Lower Necropolis, as explained already in the discussion of the results of a preliminary analysis (see above, *§ 3.3.2*).

Assuming that there are no significant changes in the genetic pool between the populations of the Lower and Upper Necropolises, all the observed differences can be attributed to a general improvement in living conditions and the worsening of the situation of women of childbearing age, as the results presented in the analysis of the age-at-death frequencies (*§ 3.4.2*) seem to indicate. Keeping in mind Wood's osteological paradox and its reservations (Wood et al. 1992), the greater number of *cribra orbitalia* changes in children 0–7 years old of the Upper Necropolis could mean a higher survival rate among infants subjected to the stress, giving them time to develop such lesions. This could also be reflected in an increase in the percentage of strong (score 3) changes in the 7–14 years bracket, provided that it is assumed that the strength of the expression of this pathology is a function of the duration of stress.[31] A slight decrease in the

[31] It is much more likely that it depended on many factors, including primarily its intensity.

Table 34. Number of cases of *cribra orbitalia* among adults, divided by degree of changes, taking into account sex, age-at-death brackets, and cemetery phase; n – number of individuals with orbital roof(s) examined; n_{co} – number of individuals with changes; n_{sco} – number of individuals with severe changes (score 3); % – percentage of individuals with changes (or with severe changes)

		20–35 yrs					35–55 yrs					55–x yrs				
	Sex	n	n_{co}	%	n_{sco}	%	n	n_{co}	%	n_{sco}	%	n	n_{co}	%	n_{sco}	%
Lower Necropolis	♀	8	1	12.50	1	12.50	10	2	20.00	0	0.00	2	0	0.00	0	0.00
	♂	8	4	50.00	0	0.00	13	3	23.08	1	7.69	1	0	0.00	0	0.00
	?	0	0	–	0	–	0	0	–	0	–	0	0	–	0	–
	Σ	16	5	31.25	1	6.25	23	5	21.74	1	4.35	3	0	0.00	0	0.00
Upper Necropolis	♀	31	6	19.35	2	6.45	32	12	37.50	2	6.25	12	3	25.00	1	8.33
	♂	29	10	34.48	4	13.79	38	5	13.16	1	2.63	9	2	22.22	0	0.00
	?	1	0	0.00	0	0.00	1	0	0.00	0	0.00	1	1	100.00	0	0.00
	Σ	61	16	26.23	6	9.84	71	17	23.94	3	4.23	22	6	27.27	1	4.55
?	♀	1	1	100.00	0	0.00	0	0	–	0	–	0	0	–	0	–
	♂	0	0	–	0	–	1	0	0.00	0	0.00	0	0	–	0	–
	?	0	0	–	0	–	2	1	50.00	1	50.00	0	0	–	0	–
	Σ	1	1	100.00	0	0.00	3	1	33.33	1	33.33	0	0	–	0	–
Σ	♀	40	8	20.00	3	7.50	42	14	33.33	2	4.76	14	3	21.43	1	7.14
	♂	37	14	37.84	4	10.81	52	8	15.38	2	3.85	10	2	20.00	0	0.00
	?	1	0	0.00	0	0.00	3	1	33.33	1	33.33	1	1	100.00	0	0.00
	Σ	78	22	28.21	7	8.97	97	23	23.71	5	5.15	25	6	24.00	1	4.00

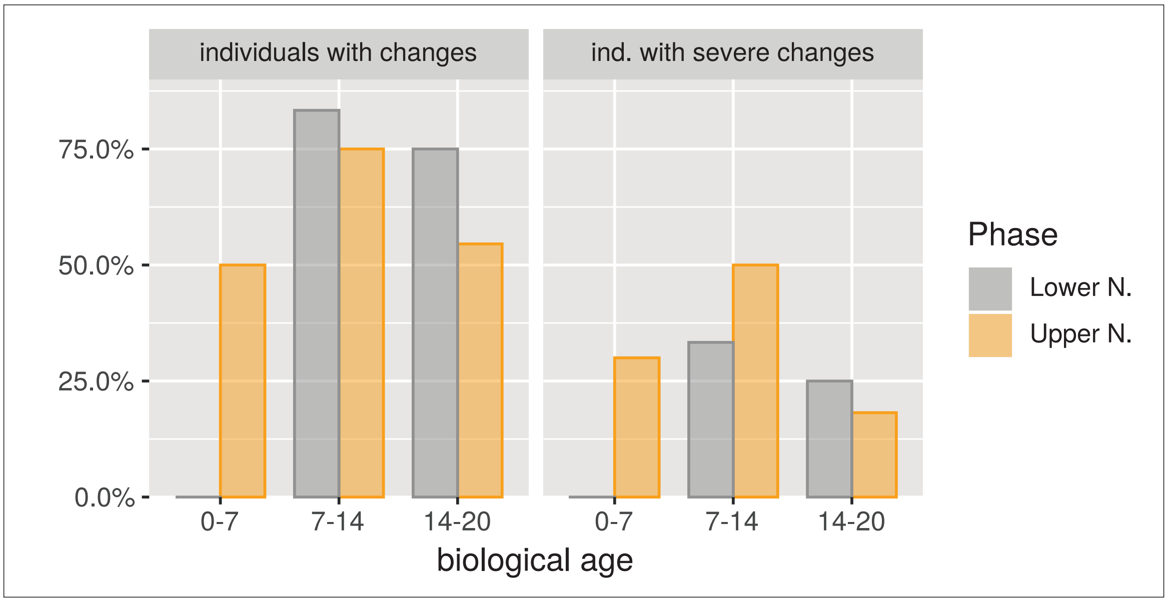

Fig. 43. Percentage of children with *cribra orbitalia* changes, divided by age-at-death brackets, taking into account cemetery phase

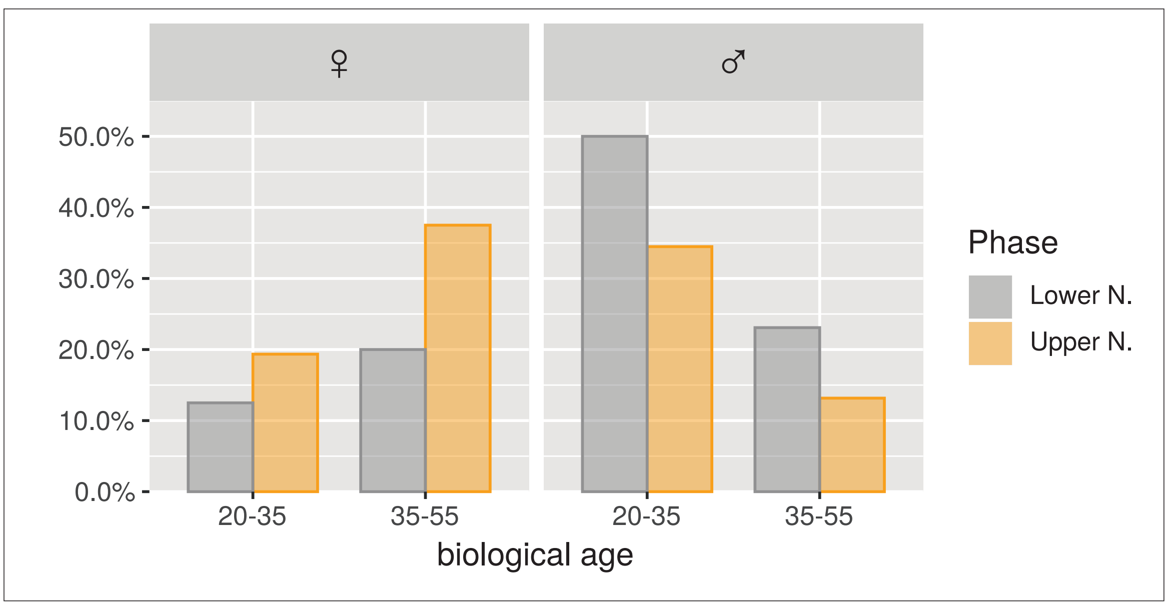

Fig. 44. Percentage of adult individuals with *cribra orbitalia* changes, divided by age-at-death brackets, taking into account cemetery phase

14–20 age group, inhibited by the deterioration of the situation of girls entering childbearing age, could be caused by a decrease in the strength of the causative factors, which would lead to a gradual obliteration of inactive porosities.

Similarly among adults, porosity was probably not obliterated among females experiencing stress connected with pregnancy, childbirth and the very difficult postpartum period, nor among men burdened with hard work, undernourished and ill. On the contrary, it can be speculated that in their case, often completely new porous lesions may have appeared. In the case of women, the stress associated with first motherhood would be so great that it could have led to death, preventing the changes from becoming visible on the skeleton. Women who survived the first crisis and lived through repeated motherhood would have developed changes more likely to be seen in mature age.[32] A closer look should be taken in the future at the possibility of porotic hyperostosis forming also in adults, because such a scenario would be the simplest explanation for the relatively higher survival rate of females displaying these changes.

Stress expressed in *cribra orbitalia* in male skeletons was obviously of a different nature. The high percentage of such changes in young men (20–35 years), the highest among adult individuals for the Lower Necropolis phase, could be the result of life-shortening factors. Much higher than among females [***Fig. 44***], it remains a mystery. There may be different reasons for this inequality between the sexes, especially when most studies point to women taking the lead in this respect (Lorkiewicz 2012: 130; Steckel and Rose 2002: 29).[33] Cultural factors are primarily the most likely reason, but a discussion of these goes beyond the scope of this study. Undernourishment and excessive physical labor are both likely, perhaps also a relatively greater exposure to malaria infections.

In view of the higher percentage of changes in both age-at-death groups of adult females from the Upper Necropolis phase compared to that of the Lower Necropolis [see ***Fig. 44***], and the mentioned increase in the frequency of those dead at the age of 20–35 years (see ***§ 3.4.2***), it may be cautiously suggested that the living conditions of females in this age group had deteriorated. Analogously for males, the drop in *cribra orbitalia* frequency in both of the examined age-at-death groups should signal improved conditions of life. These changes, however, were not reflected by the frequency of deaths in the first two age brackets of adulthood (see ***§ 3.4.2***).

3.5 Discussion

The changes that the Islamic population of medieval Alexandria was undergoing, observed in the dentition and bones of individuals buried on Kom el-Dikka, suggest an overall improvement of living conditions between the 9th and the 12th century, when the cemetery was in use. The conclusions of this study would thus appear to be restricted to the population, for which Kom el-Dikka was a cemetery of choice. But taking into account the considerable size of the excavated area and the relatively large number of examined skeletons, a cautious extrapolation to the entire Islamic community of Alexandria at the time is justified.

The frequency distribution of male age-at-death, compared across the two cemetery phases, changed insignificantly, but generally in favor of those buried in the later phase. The percentage of young adult females (20–35 years) in these statistics was clearly on the rise, demonstrating a deteriorating situation at the reproductive stage in their lives. The accompanying rise in the relative number of female individuals of advanced age (55 and more) is proof that the change, while worsening the situation for young adults, improved it for those who reached maturity (35–55 years).

[32] Patty Stuart-Macadam attributed the higher frequency of *cribra orbitalia* among women to frequent pregnancies and regular menstruation cycles in between (Roberts and Manchester 2005: 232).

[33] Stuart-Macadam is of the opposite view, noting a higher frequency of porotic hyperostosis in women only in modern times (Roberts and Manchester 2005: 232).

The situation in the case of the children is even more ambiguous. If it is assumed that the unequal sex proportions observed in the Lower Necropolis stage had an impact on the percentage of children buried on Kom el-Dikka, a slightly higher total share of the first three age groups in the total number of individuals buried in the Upper Necropolis tends to indicate a relative lack of changes in their situation in relation to those buried in the earlier phase. This would compensate for the slight shift toward the 0–7 and 14–20 age bracket. However, the lesser frequency by a third in the 7–14 age bracket could be an indirect indication of a slight improvement of living conditions for this age group.

These observations apparently do not counter the recorded frequencies of *cribra orbitalia*, assuming that they are interpreted in keeping with the hypothetical scenario presented above (*§ 3.4.5*). The premise stated there is that, in the absence of major changes in the gene pool of the studied population, there would be a slight improvement in the situation of children, that is, there would be a growing share of those surviving physiological stress long enough to develop changes in the bones. Although the summary percentage of *cribra orbitalia* among adults did not change in the transition from the Lower to the Upper Necropolis, there was a clear increase for women and a decrease for men. The factors leading to this outcome must have been different, granting females with this condition better chances to reach middle age (35–55 years), while males showing it were more likely to die earlier than those who did not have it.

The osteological paradox and potential diversity of factors causing *cribra orbitalia* prevent an independent diagnosis based on this pathological change alone. Instead, its analysis becomes an element of the narration supplementing the overall picture based on other elements and its interpretation is largely dependent on the context.

The assessment of enamel hypoplasia, which is similarly dependent on the general interpretation, also fits well with the growth hypothesis. According to this factor, the wellbeing of the youngest children grew slightly between the two chronological phases. At the same time, the survived moment of stress in the case of girls shifted slightly toward earlier years of life and in the case of boys, slightly more visibly, toward later stages of ontogenesis.

The best single and objective indicator of the wellbeing of a population is the stature of the buried individuals, hence the author's efforts to choose the most appropriate method for its reconstruction. Of the most popular long-bone length-based linear regression methods, the most consistent results for females were obtained using equations created by Ruff and others. For males, the best consistency of results was achieved when comparing the reconstructions made for different parts of the skeleton using equations by Trotter and Gleser for the East Asian group.

Stature reconstruction showed a moderately positive change in average values. The increase for males was 2.4 cm, which came close to being statistically significant. For females, the average rise was only 1.5 cm, but the direction of changes still supports the claim of a generally positive diachronic trend in the welfare of the studied population. Similarly, sexual dimorphism of this trait proved to be consistent with the observed improvement, although its interpretation depended to some extent on the direction of the changes in stature noted previously. If the population of Alexandria shared in the stabilization and economic development of Egypt under Fatimid rule, preceded by growth in the Tulunid period, the observed sexual dimorphism of stature most likely reflects a transition from improving living conditions (Wolański 2008: 126) in the Lower Necropolis phase to economic and social stabilization characterizing the population burying its dead in the graves belonging to the Upper Necropolis.

The condition of teeth, assuming a similar rate of crown wear, that is, similar susceptibility to grinding down and similar content of abrasive elements in food, showed an increase in both the frequency and intensity of caries. The differences, however, did not concern tooth caries directly for which almost no differentiation was observed. The results of the calculations changed only after ante mortem tooth loss (AMTL) was taken into account. If we assume that most of the teeth lost ante mortem had fallen out or were removed as a result of inflammatory changes due to caries, the Alexandria Muslims of the Upper Necropolis phase experienced clear changes in their diet. Caries alone cannot help to understand the direction taken by these changes. However, taking into account the trends reflected in the age-at-death and stature described above, a general positive direction of the changes in the wellbeing of a population is to be assumed.

The small number of measurements and observations despite the relatively large skeletal series, a situation resulting from a poor state of preservation of the bones, turned out to be the weakest point of these considerations. The credibility of regularities observed in the case of the Lower Necropolis was particularly affected. Comparison with analogous values observed for the Upper Necropolis phase, despite clear percentage differences, often turned out to be statistically insignificant. In addition, differences in the sets of data collected by different researchers over several dozen years led to a situation in which a significant part of the odontological and *cribra orbitalia* evaluation studies was done on a fraction (one-fifth approximately) of the skeletal material.

Another source of error that is difficult to estimate, resulting again from the poor state of preservation of the skeletons, was the impossibility of evaluating the morphological similarity of the skulls. Consideration of increased wellbeing of individuals buried in the Upper Necropolis, as compared to those known from the Lower Necropolis, is only true insofar as the morphology of Alexandria's inhabitants did not change during the period covered by the study due to migration. In particular, the additional genetic dimension given to differences observed in the stature of individuals could significantly impede the conclusions.

The sex ratio according to the burial phases that were discerned archaeologically, initially unequal due to the under-representation of females in cist graves, evened out over time: from 10 percentage points of difference to practically nil (0.68 percentage points). This could be a manifestation of, for example, a growing egalitarianism of the population in the face of death, or, more likely, a change associated with Islamization in the early phase of the cemetery. As a result, male Muslims, but foreigners to the city, who died in Alexandria, may have been buried in a place intended for the followers of the Prophet. They were probably the bulk of the visitors to the city at the time and their presence could explain the greater number of males buried in cist graves at the time of the Lower Necropolis.

When interpreting phenomena of this type, one should keep in mind that the material remains of a burial are only in exceptional cases a direct reflection of the spiritual life and individual preferences of the deceased. Since the funeral rite itself is often a kind of public manifestation of grief, the place and form of the grave seem to owe more to a collective rather than an individual perspective (Cannon and Cook 2015). Reservations notwithstanding, the results of this study point to a most probably positive change in the wellbeing of the Muslim inhabitants of early Islamic Alexandria between the 9th–10th and 11th–12th centuries. These conclusions, concerning the trend observed, will remain true even if, in the course of future work, the dating of the cemetery phases changes in any way.

Chapter 4

CHANGING LIFE IN EARLY ISLAMIC ALEXANDRIA AS RECORDED IN THE GRAVES

The period considered in this study runs from the 9th through the 12th centuries. Over the course of these 400 years Muslims living in Alexandria buried their dead in a cemetery located at the modern site of Kom el-Dikka in the center of the ancient city. The osteological remains excavated by a Polish mission working at the site for the past 60 years constitute a sample of the skeletal population sufficient in many respects to draw conclusions concerning the wellbeing of the presumably Islamic inhabitants of the city during this period. A bioarchaeological analysis of these remains, combined with a thorough revisiting of the evidence for the archaeological stratification and historical chronology of the burial ground, has led to enhanced understanding of the living conditions of this particular group.

The application of a simplified GIS solution introduced a new quality to the investigations by incorporating into the final interpretation an entire spectrum of different data, including also archival and somewhat incomplete information from more than half a century of excavations and research. The considerable set of osteological data combined with a comprehensive review of cemetery layout, in time as well as in space, has led not only to a better understanding of the development of the burial ground over four centuries (as presented in the archaeological part of this book), but has also given a framework for the bioarchaeological part of the discussion. Combining a holistic approach to the data, carrying out an interdisciplinary analysis with the application of solutions borrowed from the technical sciences, has added greater breadth to the interpretations, while extracting evidence of regularities that had previously gone unnoticed or were taken for granted.

One of these was the phasing of the cemetery. The traditional, commonly accepted, three-phase chronological division of the cemetery turned out to be in need of revision and the archaeological data, newly examined, moved the dating of the first burials at least a whole century later. Consequently, two general phases should be distinguished (retaining the existing nomenclature of phases):

- *Lower Necropolis* (9th–10th centuries)
- *Upper Necropolis* (11th and 12th centuries).

It looks, based not only on the evidence from the burial ground in question, as if the decline of the city after the Arab conquest was not as rapid and complete as is generally assumed and that Alexandria may have recovered, even if only for a short time, some of its splendor as an important sea harbor under the Fatimids.

In the absence of stratigraphic determinants, the general division of the cemetery into two instead of three phases was dictated mainly by consistency in grave form, and hence also the ritual that this reflected to some extent. The changed perspective made the patterns that gave the impulse to question the validity of the three-phase division, expressed in the frequency of particular age-at-death ranges for both sexes, much more 'natural' and comprehensible.

The ultimate collapse of the columns of the Theatre Portico, marking the complete obliteration of the architectural remains of late antique Alexandria on the Kom el-Dikka site, had until now been associated with the earthquake of 796. This has been convincingly questioned in the course of this investigation, as there were many more episodes of this kind that were similarly destructive but later in time, which could have been blamed for the collapse of columns found directly above some of the graves. And it has also been demonstrated that there is no strong justification for associating the earliest known inscriptions, paleographically dated to the end of the 7th and the beginning of the 8th century, with this particular cemetery. At the same time, the dated inscriptions from funerary stelae have been used as the most appropriate source for generating a chronological framework for funeral rites in the part of the Kom el-Dikka cemetery covered by the investigations. In fact, the inscriptions are the only category of finds that can provide reliable dates; other artifacts, including coins and glass, did not deliver any evidence in this respect. The ceramics have been useful to some extent, generally supporting a 12th-century border date for the end of burial activity at the site.

Until the 1980s, it was held that from a bioarchaeological point of view the revival accompanying the rise of Fatimid rule in the 10th and 11th centuries, which was terminated by a series of natural disasters and military conflicts, corresponded to the Middle Necropolis in the three-phase chronological division. This was interpreted as being followed by a period of improvement in the 13th and 14th century under the Mamluks (Promińska 1980: 5). It was in keeping with the state of historical knowledge at the time and the commonly accepted phasing of the cemetery. In light of modern research and the revised dating of the cemetery, Alexandria cannot be rightly perceived as the chief beneficiary of the trade revival with Europe at the time. Placing the end of the Upper Necropolis in the late 12th century puts the burial ground back into a period of prosperity although at a different time. Under the Mamluks Alexandria would have been increasingly provincial in character.

The transformation of the Islamic burial ground on Kom el-Dikka was probably to some extent a reflection of the changes taking place in the city as a whole. Generalizing specific results concerning this part of the city and transposing them to a broader urban scale is not justified, especially when dealing with a cosmopolitan center subjected to constant and varying change. However, generalizing conclusions of a more basic nature seems well-grounded. This study has shown that the transition from the Tulunids to the Fatimids was from the point of view of a two-phase cemetery a time of growing wellbeing for at least a part of the Alexandrian population. It is reflected primarily in:

- the distribution of frequencies of specific age-at-death groups, especially with regard to females,
- higher average stature of individuals, although the differences that were observed did not prove statistically significant,
- evidently greater density of burials and extended cemetery grounds, possibly involving a spread of the cemetery beyond the circuit of the city walls.

Compared to the earlier phase, the Upper Necropolis graves are not only more numerous, but they also present different funerary practices, with an apparent growth in the number of multiple burials and the number of individuals buried in one grave, reaching, more often than once, a dozen or more individuals. Stonemasonry execution in this phase is also on a much better level, the craftsmanship definitely superior to the achievements of the predecessors from the earlier phase.

In addition, the sexes start to be balanced in proportion. The superiority of males, reaching 10 percentage points in the earlier phase, due to males being buried more often in cist graves, wealthier to put it in a more straightforward manner, disappeared almost completely. This is naturally not tantamount to an egalitarianism of the sex relation in death, although even such a scenario appears probable considering that mixed burials, previously rare, became a rule in the later phase.

The even proportions of the sexes in the Upper Necropolis phase could also be an expression of a progressing religious conversion of the urban population. Previously, there would have been quite a few visiting males in the somewhat small Islamic group of inhabitants. Their presence could have disturbed the proportions of individuals of both sexes buried on Kom el-Dikka. In the later phase, even a large group of visitors to the city would have merged in with the much larger population of coreligionists.

The future of excavations of the Islamic cemetery on Kom el-Dikka should possibly concentrate on verifying the simplified phasing proposed here. More exploration in the Lower Necropolis layer, especially to the west of the late antique academic complex, would help to fill in gaps in what is known about this phase of burials and supply new osteological material for analyses, very welcome in view of the relatively small skeletal sample now available. A larger sample would provide grounds for verifying the cautious conclusions presented here. More measurements of skulls might also make feasible a morphological comparison with the skulls from the Upper Necropolis phase.

The osteological material, which includes all the skulls, teeth and child skeletons excavated since 2004, now in storage at the site, is also a good starting point for further bioarchaeologcal research, even if under the present Egyptian law physico-chemical analyses of this material are either impossible or very difficult to carry out unless done in the field. On-site work in a properly arranged field laboratory, allowing at least microscopical analyses of dental hypoplasia, detection of caries in its initial stage, and x-raying pathological changes, would supply important new data.

The possibilities of further detailed analytical work with the material are far from exhausted owing to the breadth of the presentation here. Many topics deserve a more in-depth study than was possible here, especially if bolstered with new field data.

The catalog and database developed for the purpose of this study should also continue to be updated. Including archival photographic documentation and verification of database entries with the visual record will enhance the credibility and by the same the usefulness of the collection under discussion. The end outcome, beside broadening the scope for further analyses, is a publication of the full set of data in a form allowing their continued use in research on the subject.

Appendix A

CATALOG OF GRAVES

Available online: https://doi.org/10.18150/SAWU9S

Handy guide to reading the content of this material

The catalog of graves contains a complete set of archaeological data from the cemeteries used in this study. Two kinds of structures were distinguished: superstructures, that is, tomb markers on the ground surface, and substructures, that is, grave boxes and pits. The tables with data on these two components of a grave are not in 1:1 relation. A superstructure could be related to several substructures, but not every substructure had a credible relation with a superstructure. For the Lower Necropolis, the number of cases reliably connected with one another was relatively small.

Table A.1. Tomb superstructures

The data in the table are listed in columns, with each row representing an individual superstructure.

Column	Description
item	Running number
No.	Superstructure number
sector	Excavation sector (unique within the frame of the site)
locus	Detailed localization within the sector
year	Year of exploration (discovery)
phase	Attribution to cemetery phase (according to the former three phase division): "lower", "middle", "upper"
?[1]	Phase attribution uncertainty (indicates potential error of phase record)
gis	Item identification number on GIS plan
outline	Outline of superstructure, if preserved sufficiently well to be traced in full ("yes" or "no")
?	Uncertainty of superstructure outline tracing
m asl	Elevation of the highest element preserved of a superstructure (in meters above sea level, m asl)
grave	Number of grave unit (see *Table A.2*) of which the superstructure was part
sub.	Reliable association with an identified substructure ("x" – stone or with stone roof, "o" – earth pit)
m asl	Elevation of the highest preserved element of an identified substructure (in meters above sea level, m asl)

[1] "?" in the uncertainty column marks a potential error of the record in the column to the left of it.

The last three columns of the table contain redundant data (see *Table A.2*), facilitating however easy comparison of elevation data for the super- and substructures, essential for the cemetery phasing discussion.

Table A.2. Grave units (substructures)

The data in the table are listed in columns, with each row representing an individual substructure.

Table A.2 lists underground structures, either represented in the archaeological record or believed to have existed thanks to extant superstructures. In the latter case, data was entered only for the first four columns in the table.

Column	Description
item	Running number
No.	Grave unit number
superstructure	Number of superstructure reliably linked to the grave unit
?	Uncertainty of association between grave unit and superstructure
sector	Excavation sector (unique within the frame of the site)
locus	Detailed localization within the sector
year	Year of exploration (discovery)
phase	Attribution to cemetery phase (according to the former three phase division): "lower", "middle", "upper"
?	Phase attribution uncertainty (indicates potential error of phase record)
type	Description of substructure: either "pit" or "box"
gis	Item identification number on GIS plan
outline	Outline of substructure, if preserved sufficiently well to be traced in full ("yes" or "no")
?	Uncertainty of substructure outline tracing
m asl	Elevation of the highest preserved element of an identified substructure (in meters above sea level, m asl)

For the purpose of this study, the numbering of the graves was unified in order to enable unambiguous identification of each grave unit. In doing so, care was taken to ensure the highest possible compliance with documentation produced in the past. The adopted convention calls for each grave number in the database to be made up of three elements separated by dashes.

1. Sector or trench label, kept in its original form, if present in the documentation, or taken from the localization data entered in the database.
2. Original grave number minus the prefix, if it did not have coding significance. The most frequent prefix, which was thus removed, was the letter "T" (standing for "tomb", most probably). The one exception from the rule were tombs from Sector A, which were originally prefixed with a "T"; the letter prefix was left in this case as it probably referred to the sector which was customarily called Sector T at the time.
3. Optional integer for duplicate grave numbers, signifying successive repetitions.

The format for burial features for which the original unique number could not be established was somewhat different. The designation "NN" was introduced in place of the second element and the first element was omitted, if it could not be traced as well. If two numbers were assigned to a given grave, both were given, separated by a slash; graves with three or more numbers assigned were not encountered so far.

Ideally, a single grave consisted of a grave box underground and a superstructure. However, more often than not, subterranean structures were composed of more than one feature. In addition, the underground and aboveground structures could have different numbers, even those that were undoubtedly connected. In view of the need for unambiguous identification of individual grave units, the number of the subterranean feature or else of the superstructure was assumed as the leading number, that is, if the data of a subterranean structure was missing from the documentation or its number could not be determined.

Appendix B

CATALOG OF BURIALS

Available online: https://doi.org/10.18150/SAWU9S

Handy guide to reading the content of this material

The catalogue of burials is made up of two tables, containing a full set of data from anthropological analyses collected for the purpose of this study.

Table B.1. Skeletal analyses

The data in the table are listed in columns, with each row representing a single individual.

Header	Description
item	Running number
grave	Number of grave unit yielding a given skeleton; numbers beginning with "o" indicate grave units known only from anthropological records
ind.	Arbitrary number identifying an individual skeleton within a grave unit
sex	Sex determination: F – female, M – male, ? – indeterminable
age	Biological age-at-death in years (expressed as a range); for relevant transformations see below
cribra o.	*Cribra orbitalia* changes, each eye socket scored separately on a four-grade scale (0–3) (Steckel et al. 2006: 13); observation of changes in paired elements include information on the side of the body: d – right side, and s – left side.
humerus	M1 measurement of humerus (separately for each side)
radius	M1 measurement of radius (separately for each side)
ulna	M1 measurement of ulna (separately for each side)
femur	M1 measurement of femur (separately for each side)
tibia	M1 measurement of tibia (separately for each side)
fibula	M1 measurement of fibula (separately for each side)
a.	Author of analysis: 1 – Tadeusz Dzierżykray-Rogalski and Elżbieta Promińska; 2 – Henryk Rysiewski; 3 – Karol Piasecki; 4 – Robert Mahler

The following assumptions and transformations were made in the process of unifying age determinations (examples given in parentheses):

- Assumed upper life expectancy is 100 years,[2] lower is 0;
- Fetus age-at-death is expressed in negative numbers;
- If a numerical expression in a publication was preceded by one of the abbreviations indicating approximate values: ca., env., ab.:
  - for the particular age of 0.25–0.75 years, the corresponding age bracket was assumed as ± 0.25 years (therefore "ca. 6 months" equals 0.25–0.75 years),
  - for a particular age of 1–1.5 years, the corresponding age bracket was assumed as ± 0.5 years,
  - for a particular age of 2–6 years, the corresponding age bracket was assumed as ± 1 year,
  - for a particular age of 7–24 years, the corresponding age bracket was assumed as ± 2 years,
  - for a particular age of 25–55 years, the corresponding age bracket was assumed as ± 5 years,
  - for a particular age of above 55 years, the corresponding age bracket was assumed as ± 10 years,
  - for the age bracket 2–17 years, the range was extended by ± 1 year (therefore "ca. 16–17" equals 15–18 years),
  - for the age bracket 18–24 years, the range was extended by ± 2 years,
  - for the age bracket 25–55 years, the range was extended by ± 5 years,
  - for the age bracket 60 and over, the range was extended by ± 10 years,
- The following assumptions were made regarding descriptive terminology:
  - "newborn" = age bracket 0–0.25 years,
  - "under 1" = age bracket 0–1 years,
  - "up to 1" = age bracket 0.5–1 years,
  - "juvenile" = age bracket 12–20 years,
  - "adult" = age bracket 20 years and more,
  - "old" and "*senilis*" = age bracket 55 and more.
- If a specific age was given, it was treated as a determination preceded by an abbreviation indicating approximation;
- "more" or "over" were treated as if the upper limit of an age range was set at 100 years, even if the term was included in the bracket context;
- If, instead of age, the given indications was "indeter." or "?":
  - in the case of sex determination indicated as "child", the individual's age was assumed to be in the 0–14 age bracket,
  - in the case of sex determination indicated as "juvenile", the individual's age was assumed to be in the 12–20 age bracket,
  - in the case of sex determination indicated as "F" or "M", the individual's age was assumed to be in the 14–100 age bracket,
- In the case of one evaluation as "ca. 100", the age bracket was set at 90–100 years.

[2] Virtually identical values were adopted for the "The Global History of Health Project", where the upper limit of age for an adult was set at 99.9 years (Steckel 2006: 16).

The degree of uncertainty was expressed with a grade from 0 to 2 using asterisks for the determination of sex, age-at-death, and *cribra orbitalia* changes. It was to indicate the uncertainty resulting from state of preservation, age, morphological anomalies and non-standard expression of characteristics needed for the assessment, that is, factors other than error of the observer, method, or scale. An assessment uncertainty at 0 (no star) meant no error, 1 (*) meant small or moderate uncertainty, 2 (**) high uncertainty. Elsewhere than in the author's own research, the uncertainty scales used were two-, three-, and four-grade scales. To unify data coded in this way, it was necessary to assume the following:

- in three early publications (Dzierżykray-Rogalski 1966a; 1966; 1962) single, double and triple question marks were used to signify uncertainty; one and two question marks were translated into grade 1, and three question marks were treated as grade 2 on a scale here described;
- three-grade scale adopted by the same author and Elżbieta Promińska in their later publications, transformed directly: one question mark equaled 1, two question marks were the same as 2;
- similarly, the uncertainty expressed on a three-grade scale by Henryk Rysiewski, employing "!" instead of "?", was transformed directly: one exclamation mark equaled 1, two exclamation marks were the same as 2 in the unified scale;
- a single "?" next to the verdict in Rysiewski's two-grade scale for sex determinations (Rysiewski 2000: Table 1.0) was interpreted here as corresponding to 1;
- Piasecki used the same symbols as Rysiewski to mark uncertainty in his handwritten notes; thus, a single "?" was interpreted in the same way; at the same time Piasecki replaced Rysiewski's "!" with * and used "!" instead to emphasize his certainty as to the verdict; here "?" and "*" were coded as 1, and "**" as 2.

Long bone measurements are given in the catalog, marking uncertainty on a scale from 0 to 3 with asterisks, to the right of the relevant record. No star means 0, * – 1, ** – 2, *** – 3 (numerical values attributed to this scale are described in the text, in the section discussing errors, see *§ 3.3.11*).

Table B.2. Individual odontological analyses

The odontological analyses are presented in tabular form, a separate table for each individual. Each table is tagged with the running number, grave unit number (identical with that in Table B.1), individual number, unique within a grave unit (in parentheses) and year of analysis.

Individual tables are divided into two parts corresponding to the *maxilla* and *mandibula*, with each tooth marked with a numerical code following the selected standard. The permanent teeth of the upper right side are a numbered 11 to 18, those of the upper left side 21 to 28, and those of the *mandibula*, respectively, 41 to 48 and 31 to 38.

Information for each tooth appears in a separate column with rows that include:

Row	Description
tooth and tooth socket	State of preservation of tooth and tooth socket, using the following symbols: _ no tooth socket, tooth present _u no tooth socket, tooth present, but not erupted judging by degree of development _|| no tooth socket, tooth present, broken, no traces of occlusion u tooth in alveolus, not erupted nn difficult to determine: not erupted, completely hidden in the alveolus or did not exist, or all traces of the tooth socket obliterated after tooth loss || tooth in tooth socket, broken, no traces of occlusion ( ) tooth in tooth socket v tooth lost post mortem xx tooth and tooth socket missing or impossible to locate d tooth in tooth socket, broken during life (f) no tooth, tooth socket in the process of obliteration f no tooth, tooth socket completely obliterated e tooth in tooth socket, crown broken during life, only root(s) remaining
uncertainty of assessment	Uncertainty of assessment of the state of preservation of the tooth and tooth socket (on a scale from 0 to 3)
wear	Degree of crown wear according to Smith's modified scales (Smith 1984: 46), the modification being that the scores for stages 7 and 8 were given as 7: 0 – no chance of assessment, 1 – assessment possible but no changes of a given type observable, 2–7 – degrees of wear
caries	Degree of caries according to a scale by Caselitz (1998: 218)
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