

Mechanical Engineering in Ancient Egypt, Part 84: Painting Pigments Industry during the Old and Middle Kingdoms

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Abstract— The production of painting pigments in ancient Egypt is investigated as one step in the study of the evolution of mechanical engineering in ancient Egypt. Development of pigments and its use during the Old and Middle Kingdoms are presented. Pigment elements, sources, characteristics are all outlined. The present location of the pigment applications is defined if known.

Index Terms— Mechanical engineering history, ancient Egypt, painting pigments industry, Old Kingdom, Middle Kingdom.

I. INTRODUCTION

The ancient Egyptians used natural resources to formulate and produce pigments required for their paintings for sake of decoration either on small products or huge structures. The technology they used produced pigments that could sustain environmental effects and stay fresh for thousands of years.

Colinart and Camagna (2001) in their paper about the Egyptian polychromy pointed out that paint was used in ancient Egypt for the decoration of both large-scale monuments and small objects and conveyed symbolic meaning. They examined the yellow, blue and green colors [1]. Camagna and Colinart (2003) in their study of the Egyptian green pigment analysed Egyptian blue and green pigment cakes and 50 pigment samples kept in the Louvre Museum. They proved the difference between Egyptian blue and green pigments and proposed their manufacturing processes [2]. Scott et. al. (2004) examined an ancient Egyptian cartonnage fragment with polychrome decoration to characterize the pigments, binding and construction. They showed that the pigment colors were red, blue, yellow, white, black and green [3]. Calza et. al. (2005) in their paper about X-ray analysis of pigments in decoration paintings from a sarcophagus cartonnage of an Egyptian mummy characterized the elemental composition of the cartonnage pigments and assigned the elements found in the samples. They listed 16 chemical elements [4].

Huhnerfub, Bohlen and Kurth (2006) analysed pigments from well dated ancient Egyptian boat models using TXRF analysis. They studied three groups of colors originated from white, red and blue/green paints [5]. Shortland, Hope and Tite (2006) applied quantitative analysis of a range of cobalt blue painted pottery and confirmed that the Western Desert was the source of the cobalt blue pigment [6]. Ambers, Stacey and Taylor (2007) investigated pigmental inlays from the tomb of Nefermaat from the 4th Dynasty (2600 BC) located in the British Museum. The inlays had yellow, olive-yellow, green, red, red-brown and black colors [7].

Panagiotaki, Tite and Maniatis (2008) outlined that the Egyptian blue was a multi-component material where color was due to the presence of calcium-copper-tetra silicate crystals. They presented samples of Egyptian blue beads from the 19th century BC [8]. Scott (2010) announced that Egyptian pigments included the most successful synthetic blue pigment used for more than 2500 years. He reviewed the nature of some Egyptian pigments such as malachite, azurite, green earth and calcite. He examined a group of several 26th Dynasty coffins from the collection of the San Diego Museum of Man [9]. Mahmoud (2011) in his study of ancient pigments from the mortuary temple of Pharaoh Seti I of the 19th Dynasty applied different analytical techniques to characterize some ancient pigments from samples collected from the wall paintings of the Pharaoh temple at Qurna. His results identified different pigments used in the polychromatic decorations of the temple. His analysis showed that the blue and white pigments comprised 9 elements, the red pigment comprised 8 elements and the yellow pigment comprised 10 elements [10]. Loyson (2011) in his study of the chemistry in the time of the Pharaohs outlined that the beautiful paintings in the tombs of ancient Egyptian Pharaohs and high officials are often still as fresh as when painted, and the Egyptians were excellent at using naturally colored materials. He presented the chemical substances for some of the ancient Egyptian pigments as: red (iron oxide, red ochre), yellow (clay mixed with iron, yellow ochre), blue (Egyptian blue), Pale blue (azurite), black (charcoal), green (malachite, mixing yellow and blue), grey (mixing limestone and charcoal) and white (calcium carbonate) [11].

Mahmoud (2012) characterized some ancient pigments from the painted reliefs of the tomb of Djehutyemhab from the Ramesside Period. His results revealed the blue pigment, turquoise-green pigment, the yellow pigment, and the red pigment [12]. Mahmoud and Papadopoulou (2013) characterized some pigments from the tomb of Nakht-Djehuty from the time of Pharaoh Ramses II at El-Qurna. Their analysis revealed the chemical composition of the Egyptian blue, green, red, yellow and white pigments [13]. Abdelaal, Mahmoud and Detalle (2014) identified the pigments used to decorate a wooden coffin found in Saqqara excavation as Egyptian blue/green with Cu, Si, Ca and Cl as main elements, black pigment with carbon black. They showed that the binder used was (probably) egg volk and white egg with linseed oil [14].

Gimenez (2015) studied the composition of the blue and green pigments used in the originally used Egyptian blue pigment [15]. Cororan (2016) outlined that the use of the Egyptian blue can be dated to the end of the Predynastic era and its production in ancient Egypt represented the oldest technology for an artificially produced pigment in the world [16]. Hassaan (2016) in his investigation of the pottery industry in ancient Egypt during the Middle and New Kingdoms presented the use of pigments during this period to decorate pottery products using black, white, blue, green and brown with different levels [17]. In his investigation of the faience industry during the Middle Kingdom and the Third Intermediate Period he presented a number of faience products inscribed internally or externally using black pigment [18].

Foroughi and Javadi (2017) examined the symbolic meaning of colors in ancient Egyptian painting work. They outlined that paintings can carry real and symbolic meanings such as death and immortality. They attempted to analyse symbolic meanings of colors in ancient Egyptian paintings [19]. Brons, Rasmussens, Crescenzo, Stacey and Tenorio (2018) investigated the organic components (binders and coatings) found in the polychromy of some fragmented reliefs from the Palace of Apries in Memphis (26th Dynasty). They declared that the ancient Egyptians used a rabge of organic products as binding media such as egg, animal glue, gums, plant resins, fats, oils and beeswax. The analysed samples revealed the colors: green, grey, white, blue, greenish-blue, light yellow and yellow [20]. Hassaan (2018) in his research investigating mechanical engineering in ancient Egypt presented the use of ancient Egyptians black, red, brown, white and green colors in the inscription of their papyri [21]. He presented examples for pigments palettes used by ancient Egyptians where pigments were set in circular or oval cavities for application by brushes [22], colored stelae inscribed by multi-pigments [23], wonderful designs for shabti boxes decorated by colored scenes and funerary text survived for thousands of years [24,25] and a large number of alabaster products carved and inscribed using black, green and blue pigments [26]. Hassaan (2019) in his investigation of boats industry in ancient Egypt presented a number of boat models and scenes colored using brown, yellow, green, white and blue pigments [27].

II. PIGMENT PRODUCTION IN ANCIENT EGYPT

The ancient Egyptians practiced painting produced objects since the time of Naqada III (3250 BC) [28]. They needed pigments to paint their tombs, furniture and statues starting from the Middle Kingdom [29]. Their colors carried specific significance and symbols for something in their life [30,31]. They used some primary colors with a range of color levels because of the rich mineral sources they had in Egypt and their wonderful capability of extracting those minerals. Here are some of their primary pigments:

- The white pigment: Sources (white alabaster [32], Chalk white, lead white [33], silver [34], calcite [35] and gypsum [36].
- The black pigment: Sources (black granite [37], black greywacke [38], carbon [39], lamp black and ivory black [34]. They used the granite and greywacke stones to produce black objects without need to crushing or binding processes.
- The blue pigment: Sources (Egyptian blue, a synthetic pigment produced from calcium copper silicate [40], blue from cobalt [41], Azurite, Lapis lazuli, indigo plant [34]. The Egyptian blue was capable of providing two blue codes: dark blue and sky blue as shown in Fig.1 [34]. The azurite, lapis lazuli and indigo blue pigments all provide a dark blue closer to that of the dark Egyptian blue.

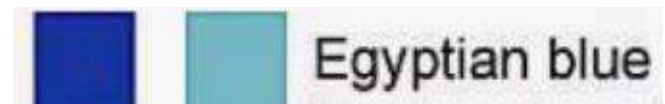


Fig.1 Two codes of the Egyptian blue [34].

- The green pigment: Sources (Malachite, Verdigris, Chryscolla and turquoise [34]). The four materials give four different codes for the green color as indicated in Fig.2 [34]. The colors range from dark green with malachite to light green with chryscolla and turquoise (green/blue) used in ancient Egypt since 3000 BC [42].

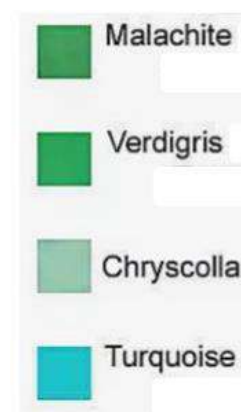


Fig.2 Four codes of the Egyptian green [34].

- The red pigment: Sources 1: Stones (red jasper, Fig.3 (a) [43], red carnelian, Fig.2 (b) [44] and red sard [45]). Sources 2 : (red lead, red achre, madder lake and carmine [33]). The detailed colors of the four materials are designated in Fig.4 The four materials give four different codes for the green color as indicated in Fig.2 [34]. The colors range from light red to brown-oriented colors.



(a) Red jasper [43] (b) Red carnelian [44] (c) Red sard [45]
Fig.3 Red stone colors [43], [44] and [45].



lead achre madder lake carmine

Fig.4 Four codes of sources 2 of red color [33].

- The yellow pigment: Sources (orpiment, lead antimonite, yellow ochre and gold [34]). The four materials give four different codes for the yellow color as indicated in Fig.5 [34]. The colors range from light to dark yellow.



Fig.5 Yellow colors of ancient Egypt [34].

III. PIGMENTS USE DURING THE OLD KINGDOM

The Old Kingdom comprised the ancient Egyptian Dynasties from the 3rd to the 6th over a time span from 2686 to 2181 BC [46]. The use of various types of pigments during the Old Kingdom is clarified through the following examples:

- The first example is a scene of geese from the tomb of Vizier Nefermaat, son of King Sneferu, the founder of the 4th Dynasty (2613-2589 BC) in display in the Egyptian museum at Cairo and shown in Fig.6 [47]. Colors used in this wonderful scene are different levels of the red color and a white color.



Fig.6 Geese scene from the 4th Dynasty [47].

- The second example is a pair statue of Prince Rahotep, son of King Sneferu from the 4th Dynasty and his wife Noferet (2613-2589 BC) in display in the Egyptian Museum at Cairo and shown in Fig.7 [48]. The statue was carved using the limestone and wonderfully painted using black, yellow, blue, green and red colors.



Fig.7 Pair statue of Rahotep and Noferet from the 4th Dynasty [48].

- The third example is scene in the tomb of Queen Meresankh, Wife of Khafre, the 4th King of the 4th Dynasty (2558-2532 BC) shown in Fig.8 [49]. The scene was drawn and painted using red, white and yellow colors.



Fig.8 Scene in the tomb of Queen Meresankh from the 4th Dynasty [49].

- The fourth example is a diorite statue of King Khafre from the 4th Dynasty (2558-2532 BC) in display in the Egyptian Museum at Cairo and shown in Fig.9 [50]. The designers used the diorite a raw material for his statue to use its black natural color.



Fig.9 Diorite statue of King Khafre from the 4th Dynasty [50].

- The fifth example is a wall painting for a bread bakery from the 4th – 6th Dynasties (2500-2300 BC) shown in Fig.10 [51]. The designer used the blue, white and different levels of the red colors.



Fig.10 Bread bakery scene from the 4th-6th Dynasties [51].

- The sixth example is a 1.422 m height greywacke pair statue of King Menkaure and his Queen from the 4th Dynasty (2490-2472 BC) in display in Museum of Fine Arts at Boston and shown in Fig.11 [52]. The designer used the natural light black color provided by the greywacke stone.



Fig.11 Greywacke pair statue of King Menkaure and his Queen from the 4th Dynasty [52].

IV. PIGMENTS USED DURING THE MIDDLE KINGDOM

The Middle Kingdom comprised the 11th and 12th Dynasties over a time span from 2050 to 1710 BC [53]. The ancient Egyptians continued to master using pigments in creating wonderful colored applications required for their daily life as will be presented by the following examples:

- The first example is a 1.83 m height sandstone statue of King Mentuhotep II, the 5th King of the 11th Dynasty (2061-2010 BC) in display in the Egyptian Museum at Cairo and shown in Fig.12 [54]. The designer used limited number of colors, mainly black, white and red.
- The second example is a faience hippopotamus from the Middle Kingdom (2033-1710 BC) in display in the Egyptian Museum at Cairo and shown in Fig.13 [55]. The ancient Egyptian designer used the Egyptian blue as the main color of the hippopotamus and decorated its body using images for Egyptian plants drawn in black.
- The third example is a 680 mm height cartonnage mummy mask of Wah from the 12th Dynasty, reign of Amenemhat I, the founder of the 12th Dynasty (1991-1962 BC) in display in the Metropolitan Museum of Art at New York and shown in Fig.14 [56]. The designer used the colors: Egyptian blue, yellow, white, red (two levels) and blue-white mix.



Fig.12 Sandstone statue of King Mentuhotep II from the 11th Dynasty [54].



Fig.13 Faience hippopotamus from the Middle Kingdom [55].



Fig.14 Cartonnage mummy mask from the 12th Dynasty [56].

- The fourth example is a painted relief from the tomb of official Cheti from Early 12th Dynasty (1980 BC) [57]. The painted scene is wonderful and look if it was just painted. The designer used the Egyptian colors: red (different levels), green, black, white and black.



Fig.15 Colored relief from the tomb of Cheti from the 12th Dynasty [57].

- The fifth example is a wall painting from the tomb of Sirenput II, Nomarch during the reign of Kings Senusret II and Senusret III of the 12th Dynasty (1929-1839 BC) shown in Fig.16 [58]. The designer different colors for his scene and hieroglyphic text. He used the blue, green, red, white and black colors in painting an outstanding scene fully colored and bounded by a thick colored frame.



Fig.16 Colored relief from the tomb of Sirenput II from the 12th Dynasty [58].

- The sixth example is a necklace of Princess Sithathoryunet, reign of King Senusret II of the 12th Dynasty (1897-1879 BC) in display in the Metropolitan Museum of Art at New York and shown in Fig.17 [59]. This is a wonderful piece of jewellery produced from natural colored materials such as gold, carnelian, lapis lazuli, turquoise and green feldspar providing the wonderful colors appearing in Fig.17.
- The seventh example is an unearthed coffin of a Noblewoman Sattjeni from the 12th Dynasty, reign of King Amenemhat III (1860-1814 BC) discovered in Qubbet el-Hawa, West Aswan of Egypt and shown in Fig.18 [60]. The coffin was painted using the Egyptian blue and the black pigments.



Fig.17 Necklace of Princess Sithathoryunet from the 12th Dynasty [59].



Fig.18 Coffin of Sattjeni from the 12th Dynasty [60].

- The eighth example is a shen amulet of Reniseneb from the 12th-13th Dynasties (1810-1700 BC) of the Middle Kingdom shown in Fig.19 [61]. The amulet was produced from carnelian (red color) with a golden frame (yellow color).



Fig.19 Shen amulet of Reniseneb from the 12th-13th Dynasties [61].

V. CONCLUSION

- The use of pigments in ancient Egypt during the Old and Middle Kingdoms was investigated.
- The sources of the white, black, blue, green red and yellow pigments were assigned with relevant graphical illustrations.

- The use of pigments during the Old Kingdom was investigated through the presentation of some applications from the 4th to 6th Dynasties covering the use of synthetic and natural pigments.
- The colors within each application were assigned according to the classification presented in the paper.
- The use of pigments during the Middle Kingdom was investigated through the presentation of some applications from the 11th to 13th Dynasties
- The Egyptian pigments either synthetic or natural could sustain the environmental effects for thousands of years.
- The whole world is still carrying research on the characteristics of the Egyptian pigments and discovering new features every day.

REFERENCES

- [1] S. Colinart and S. Camagna, "Egyptian polychromy: Pigments of the Pharaonic palette", 2001.
- [2] S. Camagna and S. Colinart, "The Egyptian green pigment: Its manufacturing process and links to Egyptian blue", *Archaeology*, vol.45, issue 4, pp.637-658, 2003.
- [3] D. Scott et. al., "An ancient Egyptian cartonnage broad collar", *Studies in Conservation*, vol.40, pp.177-192, 2004.
- [4] C. Calza, et. al., "X-ray microfluorescence analysis of pigments in decorative paintings from sarcophagus cartonnage of an Egyptian mummy", *International Nuclear Atlantic Conference*, Santos, Brazil, 6 pages, 28 August – 2 September, 2005.
- [5] K. Huhnerfub, A. Bohlen and D. Kurth, "Characterization of pigments and colors used in ancient Egyptian boat models", *Spectrochimica Acta, Part B: Atomic Spectroscopy*, vol.64, issue 10-11, pp.1224-1228, 2006.
- [6] A. Shortland, C. Hope and M. Tite, "Cobalt blue painted pottery from 18th Dynasty Egypt", *Geological Society, London, Special Publications*, vol.257, pp.91-99, 2006.
- [7] I. Ambers, R. Stacey and J. Yaylor, "Writing that can not be erased: investigations of a box of pigmental inlays from the tomb chapel of an Old Kingdom noble", *The British Museum Technical Research Bulletin*, vol.1, pp.49-54, 2007.
- [8] M. Panagiotaki, M. Yite and Y. Maniatis, "Egyptian blue in Egypt and beyond: The Aegean and the Near East", *Proceedings of the 10th International Congress of Egyptologists*, University of the Aegean, Rhodes, pp.1768-1789, 22-29 May, 2008.
- [9] D. Scott, "Ancient Egyptian pigments: The examination of some of some coffins from the San Diego Museum of Man", *In Sita Mechanical Testing of Biological and Inorganic*, vol.35, issue 5, pp.390-396, 2010.
- [10] H. Mahmoud, "A preliminary investigation of ancient pigments from the mortuary temple of Seti I, El-Qurna (Luxor, Egypt)", *Mediterranean Archaeology and Archaeometry*, vol.11, issue 1, pp.99-106, 2011.

- [11] P. Loyson, "Chemistry in the time of the Pharaohs", *Journal of Chemical Education*, vol.88, issue 2, pp.146-150, 2011.
- [12] H. Mahmoud, "A multi analytical approach for characterizing pigments from the tomb of Djehutyemhab (TT194)", *Archeometria Muhely*, vol.3, pp.205-214, 2012.
- [13] H. Mahmoud and L. Papadopoulou, "Archaeometric analysis of pigments from the tomb of Nakht-Djehuty (TT189)", *Archeo Sciences*, vol.37, pp.9-32, 2013.
- [14] S. Abdelaal, N. Mahmoud and V. Detalle, "A technical examination and the identification of the wood, pigment and binder of an ancient Egyptian sarcophagus", *International Journal of Conservation Science*, vol.5, issue 2, pp.177-188, 2014.
- [15] J. Gimenez, "Egyptian blue and/or atacamite in an ancient Egyptian coffin", *International Journal of Conservation Science*, vol.6, Issue 4, pp.747-749, 2015.
- [16] L. Concoran, "The color blue on an animator in ancient Egyptian art", in R. Godman (Editor), "Essays in global color history", *Gorgias Press*, pp.41-63, 2016.
- [17] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part X: Pottery industry (Middle and New Kingdoms)", *International Journal of Science and Engineering*, vol.2, issue 4, pp.7-18, 2016.
- [18] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part XV: Faience industry (Middle Kingdom to Third Intermediate Period)", *International Journal of Recent Engineering Science*, vol.26, pp.1-9, 2016.
- [19] M. Foroughi and S. Javadi, "Examining the symbolic meaning of colors in ancient Egyptian painting art and their origin in environment", *Bagh-E Nazar*, vol.14, issue 52, pp.69-80, 2017.
- [20] C. Brons, K. Rasmussen, M. Crezenzo, R. Stacey and A. Tengorio, "Painting the palace of Aphis I", *Heritage Science*, vol.6, issue 6, 20 pages, 2018.
- [21] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part 62: Papyrus industry", *International Journal of Emerging Research and Technology*, vol.6, issue 1, pp.7-17, 2018.
- [22] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part 63: Palettes industry", *World Journal of Engineering Research and Technology*, vol.4, issue 2, pp.168-194, 2018.
- [23] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part 64: Stelae industry (Early Dynastic to Middle Kingdom)", *International Journal of Advanced Research in Management, Architecture Technology and Engineering*, vol.4, issue 3, pp.1-9, 2018.
- [24] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part 65: Stelae industry (Second Intermediate Period and New Kingdom)", *International Journal of Engineering and Techniques*, vol.4, issue 2, pp.42-53, 2018.
- [25] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part 69: Shabti boxes inscriptions", *International Journal of Engineering and Techniques*, vol.4, issue 3, pp.436-448, 2018.
- [26] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part 76: Alabaster products inscription", *International Journal of Emerging Engineering Research and Techniques*, vol.6, issue 10, pp.12-23, 2018.
- [27] G. A. Hassaan, "Mechanical Engineering in ancient Egypt, Part 81: Boats industry during Predynastic to Middle Kingdom", *World Journal of Engineering Research and Technology*, vol.5, issue 2, pp.103-132, 2019.
- [28] L. Lee and S. Quirk, "Painting materials", in P. Nicholson and I. Shaw (Editors), "Ancient Egyptian materials and technology", Cambridge University Press, 2000.
- [29] Wikipedia, "Egyptian blue", https://commons.wikimedia.org/wiki/Egyptian_blue, 2019.
- [30] M. May, "Continuity in color: The persistence of symbolic measuring in myth, tales and tropes", University of Honors Program Thesis, Georgia Southern University, 2016.
- [31] M. Foroughi and S. Javadi, "Examining the symbolic meaning of colors in ancient Egyptian painting art and their origin in environment", *Bagh-e Nazar*, vol.14, issue 53, pp.69-80, 2017.
- [32] Ancient Egypt Online, "Meaning of white in ancient Egypt", <https://www.ancientegyptonline.co.uk/colourwhite.html>, 2010.
- [33] E. Abdel-Mageed and S. Ibrahim, "An Egyptian colors as a contemporary fashion", *Journal of the International Colour Associating*, vol.9, pp.32-47, 2012.
- [34] A. Evans, "Colors of ancient Egypt", <http://www.thoughtco.com/color-of-ancient-egypt-43718>, 2019.
- [35] <http://www.liverpoolmuseums.org.uk/wml/collections/antiquities/ancient-egypt/item-295169.aspx>, 2018.
- [36] D. Scott, "A review of ancient Egyptian pigments and cosmetics", *Studies in Conservation*, vol.61, issue 4, 2016.
- [37] Royal Society of Chemistry, "Egyptian pigments and materials", B002.
- [38] Trendstones, "The colours of granite", <http://trendstones.nz/the-colours-of-granite>
- [39] Wikipedia, "Greywacke", <http://en.wikipedia.org/wiki/Greywacke>, 2019.
- [40] The Fitzwilliam Museum, "Color and culture: Ancient Egypt", Galleries 19 and 20.
- [41] Ancient Origins, "Egyptian blue: The oldest artificial pigment", <https://www.ancient-origins.net/ancient-technology/egyptian-blue-oldest-artificial-pigment-ever-produced-001745>
- [42] Science Daily, "In search of key blue ingredient in ancient Egyptian pottery", <https://www.sciencedaily.com/releases/2010/03/100317121354.htm>, 2010.
- [43] Wikipedia, "Turquoise (color)", [http://en.wikipedia.org/wiki/Turquoise_\(color\)](http://en.wikipedia.org/wiki/Turquoise_(color)), 2019.
- [44] Wikipedia, "Jasper", <http://en.wikipedia.org/wiki/Jasper>, 2019.
- [45] Wikipedia, "Carnelian", <http://en.wikipedia.org/wiki/Carnelian>, 2019.
- [46] Wikipedia, "Onyx", <http://en.wikipedia.org/wiki/Onyx>, 2019.
- [47] Wikipedia, "Old Kingdom of Egypt", https://en.wikipedia.org/wiki/Old_Kingdom_of_Egypt, 2019.
- [48] Alamy, "Wall painting portraying wild geese from Meidum mastaba", <https://www.alamy.com/stock-photo-egyptian-civilization-old-kingdom-dynasty-iv-wall-painting-portraying-133160371.html>, 2019.
- [49] Natural Earth Paint, "Natural earth paint through the ages: Ancient Egypt", <https://www.naturalearthpaint.com/blogs/naturalearthpaint-com/natural-earth-paint-through-the-ages-ancient-egypt>, 2017.
- [50] Wikipedia, "Middle Kingdom of Egypt", https://en.wikipedia.org/wiki/Middle_Kingdom_of_Egypt, 2018.
- [51] Alamy, "Diorite statue of King Cephren", <https://www.alamy.com/diorite-statue-of-king-cephren-builder-of-the-second-pyramid-at-giza-egypt-khafra-khafre-khefren-or-cephren-was-an-ancient-egyptian-king-pharaoh-of-4th-dynasty-during-the-old-kingdom-image186366766.html>
- [52] Alamy, "Egyptian wall painting showing the making and baking of bread", <https://www.alamy.com/stock-photo-egyptian-wall-painting-showing-the-making-and-baking-of-bread-c-2500-139355089.html>, 2019.
- [53] Khan Academy, "King Menkaure and Queen", <https://www.khanacademy.org/humanities/ap-art-history/ancient-mediterranean-ap/ancient-egypt-ap/a/king-menkaure-mycerinus-and-queen>, 2019.
- [54] Wikipedia, "Middle Kingdom of Egypt", https://en.wikipedia.org/wiki/Middle_Kingdom_of_Egypt, 2019.
- [55] Famous Pharaohs, "The statue of Mentuhotep II", <https://famouspharaohs.blogspot.com/2017/08/the-statue-of-mentuhotep-ii.html>
- [56] AGE Foto Stock, "Standing hippopotamus, blue Egyptian faience", <https://www.agefotostock.com/age/en/Stock-Images/Rights-Managed/Z4Q-2618662>, 2019.

- [56] Metropolitan Museum, "Funerary mask of Wah", <https://www.metmuseum.org/art/collection/search/545116> , 2019. .
- [57] Alamy, "Grave relief of Vheti, Middle Kingdom, Early 12th Dynasty", <https://www.alamy.com/grave-relief-of-the-cheti-middle-kingdom-early-12th-dynasty-circa-1980-bc-chr-egypt-m-the-relief-shows-cheti-and-his-wife-in-front-of-a-lavishly-furnished-offering-table-a-son-of-the-couple-brings-another-beef-leg-image221830270.html> , 2019.
- [58] Alamy, "Wall painting in tomb of Srinput II", <https://www.alamy.com/stock-photo-wall-painting-in-tomb-of-sirenput-ii-the-tombs-of-the-nobles-aswan-11361121.html>, 2019.
- [59] Commons Wikimedia, "Pectoral and necklace of Sithathoryunet with the name of Senusret II", https://commons.wikimedia.org/wiki/File:Pectoral_and_Necklace_of_Sithathoryunet_with_the_Name_of_Senwosret_II_ME_T_16.1.3a_b_EGDP019659.jpg , 2018.
- [60] N. Klimczak, "Tomb of 12th Dynasty Royalwoman unearthed in Egypt", <https://www.ancient-origins.net/news-history-archaeology/tomb-12th-dynasty-noblewoman-unearthed-egypt-005961> , 2016.
- [61] Metropolitan Museum, "Shen amulet of Reniseneb", https://www.metmuseum.org/art/collection/search/100001166?rpp=60&pg=11&ft=*&when=2000-1000+B.C.&where=Egypt&pos=656 , 2019.

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