Prokudin-Gorskii's technique of colour photography: colour separation, additive projection and pigment printing

Nadezhda Stanulevich[1, 2]

[1] *The Laboratory of Museum Technologies, Peter the Great Museum of Anthropology and Ethnography (the Kunstkamera), Saint Petersburg, Russia. nstanulevich@gmail.com*

[2] *National Research University 'Higher School of Economics', Saint Petersburg, Russia. nstanulevich@hse.ru*

ABSTRACT

Russian scientist and photographer Sergei Prokudin-Gorskii studied the additive method of colour photography at Adolf Miethe's laboratory in Berlin at the beginning of the twentieth century. In December 1902, Prokudin-Gorskii gave the first colour presentation at the photography section of the Imperial Russian Technical Society. Prokudin-Gorskii photographed the Russian Empire between 1905 and 1915. Based on colour separation, he had successful optical colour projection and produced different types of colour prints. The Library of Congress purchased the main part of the negatives and reference print albums from his sons in 1948. Details of his technique contain in patents, articles and reports.

KEYWORDS Colour photography, Colour separation, Additive projection, Pigment printing, Prokudin-Gorskii, Additive technology

RECEIVED 08/12/2021; **REVISED** 18/01/2022; **ACCEPTED** 28/01/2022

1. Introduction

To record the word in colour was a mimetic dream shared by Russian photographer Sergei Prokudin-Gorskii (1863-1944). Prokudin-Gorskii's technique for producing colour images was an additive colour screen process. He took more than 3500 colour photographs and most of the colour separate glass negative preserved by the Library of Congress during his activity. Thanks to new digital technologies, Prokudin-Gorskii's photographic legacy is becoming known worldwide.

The photo historian Sergei Morozov (1955) was one of the first soviet researchers who mentioned the activities of Prokudin-Gorskii as a practical photographer. An important place in the study of the photographic heritage of Prokudin-Gorskii belongs to the works of the candidate of pedagogical sciences, Professor Svetlana Garanina. In her first paper about the photographer (Garanina, 1970), she told about the details of shooting the anniversary portrait of Leo Tolstoi in Iasnaia Poliana in May 1908 and Prokudin-Gorskii's note about the technique of colour photography. Professor Garanina published about ten articles with biographic details and descriptions of Prokudin-Gorskii's photographs.

The authors of the first foreign publications about Prokudin-Gorskii (Wall, 1925; Friedman, 1945) gave characteristics of the contribution of scientists from different countries to the development of colour photography, indicating the patents, including the information about Prokudin-Gorskii. The albums with the colour images printed by Prokudin-Gorskii's negatives from the Library of Congress Collection describing the photographer's biography and career are the primary publication type on a historical topic. One of the first English albums (Allshouse, 1980) also presented the research on the history of the development of colour photographic processes and, in particular, the additive method (Goldsmith, 1980). Some new facts from scientific biography photographer and analysis of his practical publications were published by Professor William Brumfield's cooperation research and Library of Congress staff (Brumfield, 1990). The Library of Congress annual newsletter describes the state of conservation of the collection, including glass negatives (Robb, 2001). A recital of various publications and projects that appeared after the digitization of Prokudin-Gorskii's collection can be found in the article (Leich, 2017). Still, most researches focused on the sampler of Russia's past in colour, not on the details of the photographic process. This is mainly because most sources exist only in Russian and have not been previously translated.

In this paper, the photographic articles, different reports and patents are analysed from the point of view of the scientific biography of the photographer and technical details of the additive colour process and further uncovered the history of the photographic heritage of Sergei Prokudin-Gorskii.

2. Prokudin-Gorskii science biography

Scientist, inventor, entrepreneur, and colour photographer Sergei Prokudin-Gorskii was born into a noble Russian family on 18 (30) August 1863 in Vladimirskaia province (Stanulevich, 2019). In October 1886, Prokudin-Gorskii enrolled as an irregular student at Saint Petersburg University. In the first semester, he listened to chemistry lectures by Dimitri Mendeleyev, inventor of the periodic table (Prokudin-Gorskii, 1886). Mendeleyev influenced the young Prokudin-Gorskii's interest in chemistry. Also, Prokudin-Gorskii attended a class in analytical chemistry in autumn 1887, and the following autumn, he stopped his education at University (Prokudin-Gorskii, 1888). Two months early, he started to be an irregular student at the Imperial Medical Army College. In the fall semester of 1889, he also stopped his education at College (*Certificate*, 1890). He did not complete the cycle of higher education, but the knowledge gained formed his main interests and skills: chemistry and photography.

In 1890 Prokudin-Gorskii married Anna Lavrova, daughter of an industrialist Alexander Lavrov, an active member of the Imperial Russian Technical Society (IRTS). Lavrov appointed his son-in-law director of the executive board of his steelworks, located in Gatchina near Saint Petersburg. In 1896 Prokudin-Gorskii started to be a member of the chemistry section of the IRTS. Two years later, he was a member of its photography section, presented an illustration report *On Photographing Meteor Showers*. In the same year, he was one of the exhibitors at the 5th Photographic Exhibition at the IRTS with 23 gold and platinum-toned celloidin prints. For this exhibition, he used isochromatic and panchromatic plates by Ilford and Lumière to make photographs of oil paintings from a private collection of I. Zabel'skogo (*Index for the 5th Photographic Exhibition organized by 5th department of IRTS*, 1898).

Prokudin-Gorskii maybe took his first photographs near summer 1892. He mentioned photographing in Yalta in one of his first photo articles (Prokudin-Gorskii, 1897). This could be due to professional interest and an increased interest in photography in everyday life. In addition, the birth of children in the family of Sergei Prokudin-Gorskii could serve as an appeal to photography - the eldest son Dmitry was born on 22nd January 1892 (Korlyakov, 2009).

Since 1898, Sergei Prokudin-Gorskii wrote reviews to international photographic news for the IRTS. I supposed

that he concentrated his attention on colour photography by these researches. On 30th October 1898, he had a report at the IRTS about new Ives' magic lantern for the projection from three colour-separated slides. Prokudin-Gorskii emphasized the merits of colour reproduction, indicated the considerable labour input in production and long exposure that embarrassed the photographing animate objects (Prokudin-Gorskii, 1899). He mentioned more than twenty years later in the British Journal of Photography pages (Prokoudine Gorsky, 1920):

"Certainly, such an arrangement, i.e., exact superposing - on one and all - of three pictures through three coloured screens is a slow process, but if it is done at once it series continually, and therefore the most advantageous condition for such projection is a permanent hall where the apparatus is fixed and will not be moved. With such an optical apparatus colour projection was shown for the first time by Mr. F. E. Ives. This apparatus was modified by myself, and from the point of view of rapidity of arrangements and quality it gave better results, and, having shown my pictures in different parts of Russia by means of this apparatus. I had absolutely no competitors, not even Autochrome, which made its appearance long ago, and which remains within close limits of private circles. More than a hundred projections shown by myself playing convinced me of the great interest of audience, regardless of their composition. It is only necessary that the show be accompanied by verbal explanation; no lecture is essential, but just a simple explanation of what it being shown."

On 29th January 1899, Prokudin-Gorskii demonstrated John Joly's colour photography of a parrot to IRTS' members. Interestingly, this type of bird was a favourite subject for photographing by all scientists who created colour photography. For example, Alexandre-Edmond Becquerel (1820-1891) exhibited at the International Exhibition in Paris in 1855 one of his photographic plates depicting a parrot (Pénichon, 2013). One of the leading figures in three-colour photographic processes - Louis Ducos du Hauron (1837-1920) demonstrated at the Conservatoire national des arts et métiers in 1881 héliochrome depicting a parrot and a rooster, made in 1879 (Lécuyer, 1945). The photographers' choice for the shooting of the parrot was probably caused by the multi-coloured plumage, which made it possible to demonstrate success in obtaining colour images and the reliability of colour reproduction of one or another photographic method.

Two months later, on 19th March 1899, Sergei Prokudin-Gorskii showed at IRTS a stereoscopic photochromoscope by Lumière (*The photography section of the IRTS meeting journal on 19th March 1899*, 1899).

3. Colour separation, additive projection and pigment printing

In the early 1900s, Prokudin-Gorskii opened in Saint Petersburg a photographic laboratory called "Prokudin-Gorskii's Art Photomechanical Studio". At the first time, it produced photocopies from artworks, and then colour postcards and slides usually based on Prokudin-Gorskii's separate negatives. Also, Studio specialised in making photolithography and microphotography. At the beginning of the twentieth century, he studied an additive method of colour photography intensely from Adolf Miethe in Berlin. By analysing the dates, titles, and lists of participants of the IRTS' meetings, we understand that Prokudin-Gorskii's education in Berlin ended in December 1902. As mentioned in some articles, documents about his travel to Europe in the late 1880s (Adamson, 2002, p. 108; Allshouse, 1980, p. X) were not found during ten-year research. Maybe, he had some travels to Berlin in the late 1880s, but for the management of his father-in-law foundry, for the chemical and technical educational reasons.

As Adolf Miethe, Prokudin-Gorskii created his photographs using a camera that exposed one oblong glass negative plate three times in rapid succession through three colour filters. Prokudin-Gorskii photographed with shutter by Thornton-Pickard and different objectives by Steinheil or Voigtländer (Prokudin-Gorskii, 1906c) because the usage of colour filters extended the exposition time and demanded high lens speed.

In 1903 Prokudin-Gorskii published his results in booklet form, Isochromatic Photography with Instant Hand Cameras and recommended using isochromatic plates by Otto Perutz's factory-like a "perchromo" and "perorto platen" (Prokudin-Gorskii, 1903). The emulsion of these plates was made with the guidance of Adolf Miethe. As an analogue of Perutz's plates, Prokudin-Gorskii mentioned isochromatic products of different companies, for example, Aktien Gesellschaft fur Anilin Fabrikation, Edward's, Lumière, and Ilford.

His first known lecture on three-colour photography was delivered on 13th December 1902, reported on colour slides by Adolf Miethe (Adamson and Zinkham, 2002). Prokudin-Gorskii ordered the projector in a German factory. Later, this apparatus was destroyed after his leaving Russia in 1918 (Anon., 1932). A screen for projection was painted in white colour without blue pigment and then mounted to a black frame. A black drop-down curtain was lifted and closed for the projection of each image (*The photography section of the IRTS meeting journal on 4th February 1905*, 1905). Prokudin-Gorskii was one of the photographers who lectured about the regions

he travelled, using the colour slides he had produced. His son Dmitry (1892-1963) often operated the lantern (Anon, 1910). Sergei Prokudin-Gorskii always had chosen a unique series of pictures that served the purpose of an action to viewers. It can be, for example, photographs of flowers (Fig. 1), which have an excellent appeal for Empress Alexandra in May 1909.

Fig. 1. Apricot flowers (dried apricots). Samarkand. 1905-1915. Sergei Prokudin-Gorskii. Digital colour rendering from digital files from glass negatives. Prokudin-Gorskiĭ Collection (Library of Congress). LC-DIG-ppem-02155.

At the first shows, Prokudin-Gorskii, probably, used a magic lantern with three lenses with attached colour filters that matched the red-green-blue separations on the glass slide. They formed a single, full-colour image when projected on a white screen in perfect registration. Later he tried to create a system with one beam and multilayer transparencies. As he mentioned in The British Journal of Photography publication (Prokoudine Gorsky, 1920):

The methods for the producing of transparency for the projection colour images existing at present can be divided into three groups:

1. Autochrome and other similar methods [...]
2. Different methods of gluing together films to films or to a glass […]
3. Colouring of the diapositives, even if made sometimes with very transparent colours [...]

After 1904 Prokudin-Gorskii began to develop a colour-sensitive photographic plates. He had perfected a new method that gave equal sensitivity throughout the spectrum within a year. Commenting on his colour images published in the journal Fotograf-Liubitel', Prokudin-Gorskii mentioned that he processed a special emulsion that hypersensitised the Ilford "red label" plates (Prokudin-Gorskii, 1906c). We found the same information (Evdokimov, 1914) on paper about trichromatic prints by Alexander Evdokimov, Prokudin-Gorskii's partner, between 1902 and 1914. Prokudin-Gorskii described drying the plates after sensitisation in his report at VI International Congress of Pure and Applied Chemistry in Rome in 1906 (Prokudin-Gorskii, 1906a) and one of the articles on colour photography (Prokudin-Gorskii, 1906b). The patent for the process of sensitisation of the emulsion was not detected in different databases and archives.

Sergei Prokudin-Gorskii started to obtain patents in Great Britain, the USA, France and Russia before the First World War for production of coloured slides, improvements in and relating to optical systems for the photographic camera, making multiple copies of colour slides etc. Some of them are mentioned in books like History of three-color photography (Wall, 1925) and History of colour photography (Friedman, 1945). From the Russian patent (*Patent #27542 was issued on 30th October 1914*, 1914), we can derive that he started to use colour separate negatives exposed through red, green and blue filters for printing two autotype clichés (for magenta and yellow inks) instead of making a glass slide like a "sandwich". Through gelatin solution, magenta and yellow images were transferred from paper support to one glass plate. The third part was a cyan slide printed from a halftone negative that had been exposed through a red filter. The last step was mounting both-glass slides - the magenta and yellow on one and the cyan slide on the other – together so that its result is one lantern slide. Sergei Prokudin-Gorskii wrote that the slides looked like a pigment colour image in projection.

The process of making clichés for colour printing described by Alexander Evdokimov in the first decade of the twentieth century contained the following steps: colour separation by the photographed through the three colour filters; contact printing of transparencies from each separated negatives; shooting from the scales; printing autotype negatives and then making clichés on copper or zinc (Evdokimov, 1914). In 1905 and 1906, Prokudin-Gorskii mentioned that Frankenstein-London Company dyes were used in his studio in Saint Petersburg. For the best results, masters printed on paper four colours (yellow, red, blue and black) one after with a difference like 24 hours (Fig. 2, 3). Prokudin-Gorskii started repeating the halftone process for each subtractive colour to make postcards with his colour-separated negatives since the same year.

Fig. 2. Yellow, red, blue and yellow plus red parts of colour prints. Prokudin-Gorskii, S. (1905) Photomechanical work. Saint Petersburg: Printing House "Public Benefit".

Fig. 3. No title. Postcard from oil painting. 1903-1905. Photographer Sergei Prokudin-Gorskii. Nadezhda Stanulevich private collection.

The Prokudin-Gorskii's Studio was a typical printing enterprise before showing colour slides for Emperor Nicolas II in May 1909. After the audience, the number of government orders increased. For example, Prokudin-Gorskii photographed the different objects for the government to publish historical albums for the centenary of the Patriotic War 1812 and the three hundred anniversary of the House of Romanov in 1913. He would also like to shoot the Emperor's ceremonial exits during the last celebration to colour cinematography. Sergei Prokudin-Gorskii began to develop different technological stages of producing colour cinematography in 1910.

Continuing his scientific activity, Sergei Prokudin-Gorskii participated in creating the Higher Institute of Photography and Photo Technique in Petrograd after the October Revolution. Realising the position of Russian industry by the end of the First World War, he decided to do business abroad. In August 1918, he left Petrograd for production colour cinema in Norway. He moved to England in 1919 and then France in 1921. Prokudin-Gorskii, with his sons, Dmitry and Mikhail, founded a company, "Societé de Photochimie Elka" named Sergei Prokudin-Gorskii's youngest daughter Helena (later a company renamed to "Gorsky Frères") in Nice in 1924.

Prokudin-Gorskii's photographs were demonstrated at the lectures Russia in Images in the different Parisian organisations in the 1930s. All pictures were black and white because an additive magic lantern had been left in Russia (Stanulevich, 2020).

Since the second part of the 1920s, the photographer started to use film in his processes. Prokudin-Gorskii mentioned that fact in his notebooks. Copy of these notes from the family collection in Paris was presented by Svetlana Garanina, the first Russian biographer of Sergei Prokudin-Gorskii, to the Polytechnic Museum in Moscow in 1995 (Danilina, 1995). These documents show the history of Prokudin-Gorskii's patent usage, describing his photographic processes' modifications during the 1920s.

On 18th December 1926, Prokudin-Gorskii had a report at the French Photography Society about making natural-colour prints on paper. In the photographer's opinion, the photomechanical property of the Elka paper was the possibility of the image being transferred to any desired surface. The image was transferred to a metallic surface and developed in hot water to remove all soluble gelatin at describing a process. The metallic silver of the films transformed into halide salt. Finally, the plates are rinsed very briefly, merely to remove the excess of the solution, and each is immersed in a dye solution, orange-red, yellow and blue. When the three dyed images have thus been produced, all that remains is transferring one of the prints to the final support and superposing the other two upon it (*Colour Photography on Paper*, 1926).

In addition, notes contributed information about the contract between Prokudin-Gorskii and Lumière's label for the making film with Prokudin-Gorskii's label – Elka. Despite the active popularisation of his photographic paper, Prokudin-Gorskii mentioned that he preferred to experiment with Kodak transferotype paper for making slides since 1927 (Prokudin-Gorskii, no date, p. 16). Kodak produced this paper to make enlarged negatives, glass positives or lanternslides, and prints upon opal glass, wood, metal tinted or other drawing paper, silk, satin, sateen, and other suitable support. In his notes, Prokudin-Gorskii explained the transition to Kodak paper because Elka paper, made at the Lumière factory by 1927, was not the best quality. The disadvantages were uneven emulsion, dirt, excessive paper relief (Prokudin-Gorskii, no date, p. 12).

Before the 1950s, "Gorsky Frères" specialized in commercial printing for Nestlé, Fléchet, L'Illustration and Figaro. Also, they partly realised an idea of creating a collection of French ethnographic types (one copy of prints was preserved by Mikhail's son Serge Procoudine Gorsky (1932-2005) in Paris). The colour prints with French views by "Gorsky Frères" are sometimes found on The Delcampe website [1].

4. Heritage of Sergei Prokudin-Gorskii

The Library of Congress purchased Prokudin-Gorskii's collection the photographer's sons in 1948, after his death in 1944. The entire collection of glass negatives and albums with sepia-tone prints was digitised in 1999 and is available worldwide on the Internet. In a 1995 interview, Anna Béraud (1930-1996), the granddaughter of Prokudin-Gorskii, said that the collection was kept in the basement (two or three square meters for each apartment) of a house at 69 rue de la Tomb Issoire, where the family lived since 1938. They were all afraid that the photographs would be spoiled without special preservation conditions (Minachin, 2003).

The Library of Congress collection includes 1902 black and white glass negatives and more than 3100 sepia-tone prints (Fig. 4) without any colour or black and white slides. The size of the glass negatives is 9 x 24 cm. The dimensions of each image frame are 8.5 cm. wide and from 7.5 cm. to 8 cm. tall. Prokudin-Gorskii mentioned in his emigrant memoirs that he printed copies of images and collected them to the album after shooting. In this way, the albums from the Library of Congress Collection were made. The author's numbering and titling were photographic prints from red filter glass negatives. Although sometimes Prokudin-Gorskii wrote this information from memory and made mistakes, researchers determine now. The sepia-tone prints with size 8 x 8 cm. mounted on fourteen albums (usually six photos on each page of the album).

Not all materials of Prokudin-Gorskii are kept in the Library of Congress and other officially declared collections. It is known from archival documents that as of 1913, the photographer shot 3350 negatives and made 1000 slides (Anon, 1913). In the case of the same subject, the Library of Congress collection may contain a set 'negative and sepia-tone print', or images are represented by only one type of material. And in the case of only having a sepia-tone print, we can see the colour image only thanks to the finds of colour prints from various publications, for example, early twentieth-century books published in cooperation with Prokudin-Gorskii's studio (Fig. 4, 5).

Fifteen black and white slides of Leo Tolstoi's Estate in Iasnaia Poliana with the size of 8 x 8 cm are preserved at the Institute of Russian Literature Collection. Twenty-four colour slides made in the 1930s on film are part of a private collection of Prokudin-Gorskii's grandson, Michelle Soussaline.

Colour postcards, posters, illustrations for publications printed by Prokudin-Gorskii based on his separated negatives are part of the collections of archives and libraries in different countries.

Fig. 4. Vyborg castle. 1904. Sergei Prokudin-Gorskii. Photographic print. Prokudin-Gorskiĭ Collection (Library of Congress). LOT 10333, no. 91.

Fig. 5. Vyborg castle. Example of colour printing. Prokudin-Gorskii, S. (1905) Photomechanucal work. Saint Petersburg: Printing House "Public Benefit".

5. Conclusion

Sergei Prokudin-Gorskii was a talented inventor who used his scientific background. The main interest of the additive process is that a black and white image is used directly as the base of the colour image. Prokudin-Gorskii wrote in emigration (Prokoudine Gorsky, 1920) that having been occupied with the problem of colour cinematograph since 1912; he concluded that the principle of three separate negatives was the most advantageous because it allowed large amplitude in the ratio of exposures. Moreover, in his opinion, these negatives can be utilised for another very useful purpose: optical colour projection and producing colour prints typographically.

In my opinion, the main contribution of Prokudin-Gorskii to the development of the additive method is the refinement of the emulsion for the plates, development of technology for creating colour slides with a transition to attempts to develop colour cinematography. Also, he selected shooting parameters for various weather conditions on the territory of the Russian Empire, created a series of surveys that included at least 3500 negatives, arranged the use of colour-separated negatives for printing colour illustrations and trained masters in his studio.

6. Conflict of interest declaration

The author declares that nothing affected their objectivity or independence and original work. Therefore, no conflict of interest exists.

7. Funding source declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

8. Short biography of the author

Nadezhda Stanulevich is a photo historian. She defended her Candidate of Science dissertation entitled *Sergei Prokudin-Gorskii and his contribution to the development of colour photography* in 2019. Most of her peer-reviewed articles focus on the history of photographic techniques or museums collections. Since September 2019, she has been a Researcher at Peter the Great Museum of Anthropology and Ethnography (the Kunstkamera).

Notes

[1] https://www.delcampe.net/en_US/collectibles/engravings/lot-de-3-tableaux-province-de-france-sous-verre-45-x-54-cm-photos-gorsky-1947-1948-voir-7-photos-159030833.html

References

Adamson, J. and Zinkham, H. (2002) 'The Prokudin-Gorskii legacy: color photographs of the Russian Empire, 1905-1915', *Comma*, 3/4, p. 109.

Allshouse, R. H. (1980) *Photographs for the Tsar: The Pioneering Color Photography of Sergei Mikhailovich Prokudin-Gorskii Commissioned by Tsar Nicholas II.* London: Dial Press.

Brumfield, W. C. (1990) 'The color photographs of Sergei Mikhailovich Prokudin-Gorskii', *Visual Resource*, Vol. VI, pp. 243-255.

Count Benkendorff, P. K. (1910) *Spisok lits, prinimavshikh uchastie v demonstratsii proektsii tsvetnoi fotografii v Vysochaishem prisutstvii, v Aleksandrovskom dvortse, 20 marta 1910 g.* [List of persons who participated in a demonstration of colour photographies projection in the presence of Emperor Nicolas II on 20th March 1910]: Ф. 468, Оп. 8, Д. 1055, Ч. I, Л. 135. The Russian State Historical Archive, Imperial Cabinet of the Russian Empire. Saint Petersburg.

Certificate (1890): Ф. 358, Оп. 1, Д. 1031, Л. 7. The Central State Historical Archive in Saint Petersburg, Demidov's school. Saint Petersburg.

'Colour Photography on Paper' (1926), *The British Journal of Photography, Monthly Supplement on Colour Photography*, 161, p. 31.

Danilina, V. (1995) *Opis' lichnogo fonda Sergeia Prokudina-Gorskogo (dokumenty i fotografii)* [List of Personal fund of Sergei Prokudin-Gorskii (documents and photographies)]: ПМ-033441/1-33. The Polytechnic Museum, Department of Written Sources. Moscow.

Evdokimov, A. (1914) 'Trekhkrasochnaia tipografskaia pechat' i ee tekhnika [Three-colour typographical print (Dreifarbendruck) and its technology]', *Zapiski Imperatorskogo Russkogo Tekhnicheskogo Obshchestva* [Bulletin of the Imperial Russian Technical Society], 1, pp. 15-18.

Friedman, J. S. (1945) *History of color photography*. Boston: American Photographic Publish Company.

Garanina, S. P. (1970) L. N. Tolstoi na tsvetnom foto [L. N. Tolstoi in colour photography], *Nauka I zhizn'* [Science and life], 8, pp. 97-99.

Goldsmith, A. (1980) 'Afterword. Prokudin-Gorskii and the Photographic Tradition', in: Allshouse, R. H. (ed.) *Photographs for the Tsar: The Pioneering Color Photography of Sergei Mikhailovich Prokudin-Gorskii Commissioned by Tsar Nicholas II*. London: Dial Press, pp. 211-215.

Korlyakov, A. (2009) *Velikii russkii iskhod* [Great Russian Exodus. Europe]. Paris: YMCA-PRESS, 2009. p. 978.

Leich, H. M. (2017) 'The Prokudin-Gorskii Collection of Early 20th Century Color Photographs of Russia at the Library of Congress: Unexpected Consequences of the Digitization of the Collection, 2000-2017', *Slavic & East European Information Resources*, 18, no.3/4, pp. 223-230.

Lécuyer, R. (1945) *Histoire de la photographie*. Paris: Baschet et C. p. 232.

List of movables of the partnership "Prokudin-Gorskii & Co" (1913): Ф. 23, Оп. 12, Д. 1925, Л. 2об. The Russian State Historical Archive, The Ministry of Trade and Industry. Saint Petersburg.

Minachin, V. (2003). '"The Splendors of Russia Collection" at the Library of Congress', in *Catalog of exhibition "The Splendors of Russia in Natural Colors. The Complete Prokudin-Gorsky 1905-1916" at the Schusev State Museum of Architecture in Moscow*. Moscow: Schusev State Museum of Architecture, pp. 31-47.

Morozov, S. A. (1955) *Russkaia khudozhestvennaia fotografiia. Ocherki iz istorii fotografii 1839-1917* [Russian art photography. Studies about the history of photography 1839-1917]. Moscow: State publishing house Iskusstvo. pp.122-125.

Pénichon, S. (2013) *Twentieth century colour photographs. The complete guide to processes, identification & preservation*. London: Thames & Hudson Ltd. p. 8.

Patent #27542 was issued on 30th October 1914 (1914): Ф. 24, Оп. 23, Д. 410, Л. 20-20об. The Russian State Historical Archive, Department of technical matter of the Ministry of Trade and Industry. Saint Petersburg.

Proekt sozdaniia Obshchestva s ogranichennoi otvetstvennost'iu po organizatsii tsvetnykh proektsii [Project of creation of the Limited Company for organisation the showing colour projections] (1932): Ф. 33, Оп. 1, Д. 5. The Polytechnic Museum, Department of Written Sources. Moscow.

Prokudin-Gorskii, S. (1886) *Zaiavlenie inspektoru studentov* [Application to the student inspector]: Ф. 14, Оп. 3, Д. 26010. Л. 2. The Central State Historical Archive in Saint Petersburg, Imperial University in Petrograd. Saint Petersburg.

Prokudin-Gorskii, S. (1888) *Proshenie rektoru Imperatorskogo Sankt-Peterburgskogo universiteta* [Application to the rector of the Saint Petersburg University]: Ф. 14, Оп. 3, Д. 26010, Л. 24. The Central State Historical Archive in Saint Petersburg, Imperial University in Petrograd. Saint Petersburg.

Prokudin-Gorskii, S. (1897) 'Plastinki d-ra I. Smita (Pis'mo v redaktsiiu) [Plates by Dr. I. Smith (letter to editorial board)]', *Russian photographic journal*, 2, p. 47-48.

Prokudin-Gorskii, S. (1899) 'Novyi pribor Aivsa dlia proektsii v natural'nykh tsvetakh (kraskakh). [New Ives' apparatus for projection in natural colours]', *Zapiski Imperatorskogo Russkogo Tekhnicheskogo Obshchestva* [Bulletin of the Imperial Russian Technical Society], 1, p. 59-60.

Prokudin-Gorskii, S. (1903) *Izo-khromaticheskaia s''emka momental'nymi ruchnymi kamerami* [Isochromatic Photography with Instant Hand Cameras]. Saint Petersburg: Printing House of Journal "Samokat". pp. 11-12.

Prokudin-Gorskii, S. (1905) *Fototekhnicheskoe delo* [Photomechanucal work]. Saint Petersburg: Printing House "Public Benefit".

Prokudin-Gorskii, S. (1906a) 'VI International Congress of Pure and Applied Chemistry in Rome', *Fotograf-Liubitel'*, 5, p. 158.

Prokudin-Gorskii, S. (1906b) 'Fotografii v natural'nykh tsvetakh [Photography in natural colours]', *Fotograf-Liubitel'*, 6, p. 179.

Prokudin-Gorskii, S. (1906c) 'K risunkam [About the pictures]', *Fotograf-Liubitel'* [Photographer Amateur], 10, p. 313.

Prokoudine Gorsky, S. (1920) 'Importance of colour photography for schools and the community in general', *The British Journal of Photography, Monthly Supplement on Colour Photography*, 161, pp. 13-15 and 19-20.

Prokudin-Gorskii, S. (no date) *Rabochaia zapisnaia knizhka S.M. Prokudina-Gorskogo* [Prokudin-Gorskii's work norebook]: Ф. 33, Оп. 1, Д. 6. The Polytechnic Museum, Department of Written Sources. Moscow.

Robb, A. (2001) 'Conservation Corner: Albums, Photos, Glass Plate Negatives, Library of Congress'. Available at: http://www.loc.gov/loc/lcib/0105/conservation_corner.html (Accessed: 6th December 2021).

Stanulevich, N. A. (2019) *Sergei Mikhailovich Prokudin-Gorskii i ego vklad v razvitie metodov tsvetnoi fotografii* [Sergey Mikhailovich Prokudin-Gorskii and his contribution to the development of colour photography]. Candidate of Science. Herzen University. p. 30.

Stanulevich, N. A. (2020) 'Magic lantern slides by Sergei Prokudin-Gorskii', in: Dellmann S. and Kessler S. (eds.) *A million pictures: magic lantern slides in the history of learning*. New Barnet: John Libbey Publishing, pp.63-72.

Ukazatel' piatoi fotograficheskoi vystavki ustroennoi piatym fotdelom IRTO. [Index for the 5th Photographic Exhibition organized by 5th department of IRTS]. 2nd ed. (1898). Saint Petersburg: Printing House of the Railway Ministry, p. 46.

'Zhurnaly zasedanii V (Fotograficheskogo) otdela I.R.T.O. Zasedanie 19 marta 1899 goda. [The photography section of the IRTS meeting journal on 19th March 1899]' (1899), *Zapiski Imperatorskogo Russkogo Tekhnicheskogo Obshchestva* [Bulletin of the Imperial Russian Technical Society], 5, p. 209.

'Zhurnaly zasedanii V (Fotograficheskogo) otdela I.R.T.O. Zasedanie 4 fevralia 1905 goda. [The photography section of the IRTS meeting journal on 4th February 1905]' (1905), *Zapiski Imperatorskogo Russkogo Tekhnicheskogo Obshchestva* [Bulletin of the Imperial Russian Technical Society], 6, pp. 227-228.

Wall, E. J. (1925) *The history of three-color photography*. Boston: American Photographic Publish Company.