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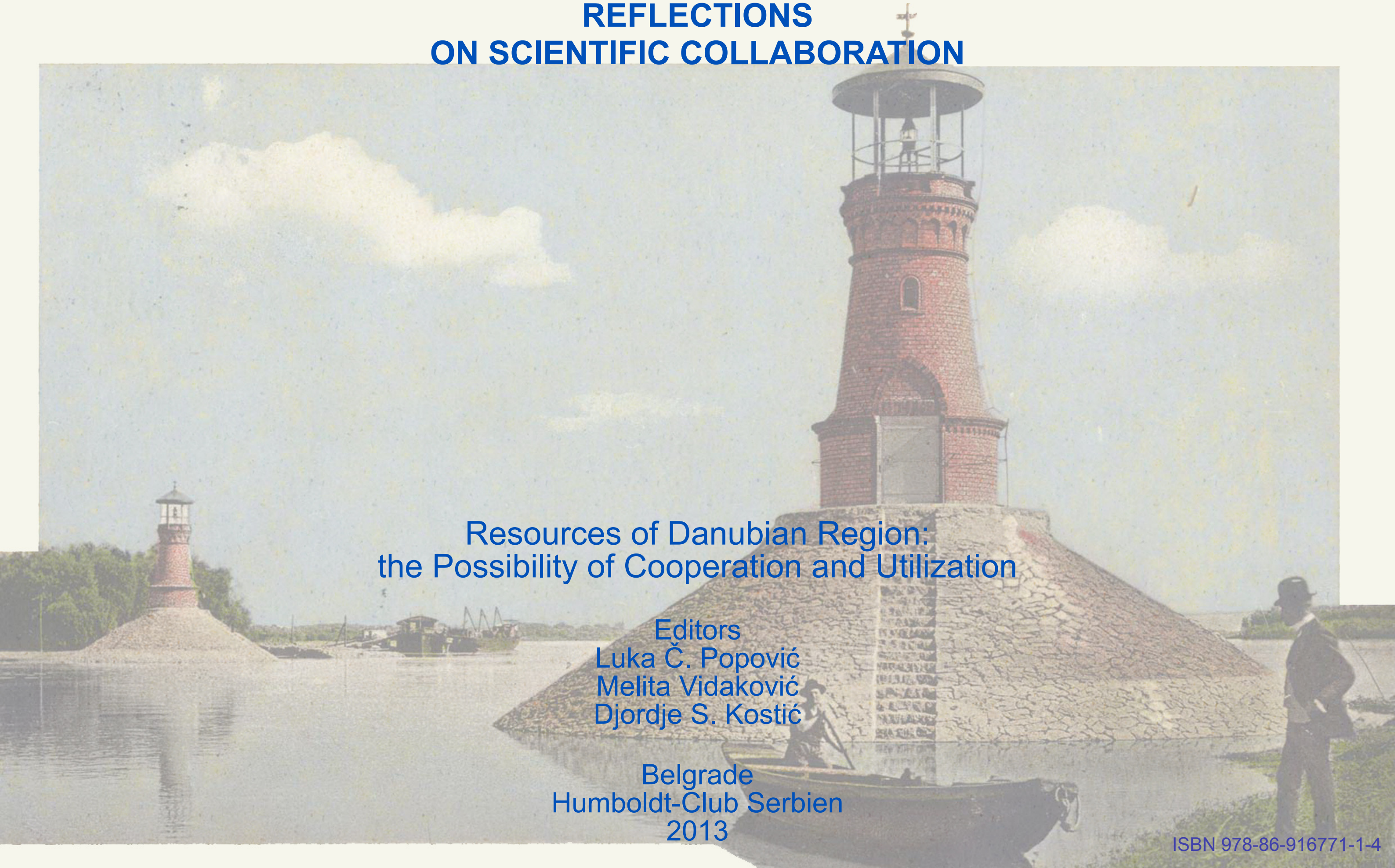
REFLECTIONS ON SCIENTIFIC COLLABORATION



Resources of Danubian Region:
the Possibility of Cooperation and Utilization

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Abctract. Cooperation in the Danube Region is a special endeavour as it combines cluster formation with international collaboration. While the success of innovative clusters is determined by local proximity, international scientific collaboration crosses borders, and the river Danube seems to mix both modes. In line with this recognition of different types of collaboration, this paper reflects on the nature of scientific collaboration and its diversity. The notion of 'co-laboring' can be seen as the literal roots of collaboration. Definitions of scientific collaboration vary from broad definitions involving co-working to more delimited definitions requiring teamwork with shared goals. In addition, scientific collaboration can be informally organised or firmly institutionalized. To date, two main approaches have dominated the study of collaboration. Bibliometric analyses catalogue rising rates of collaboration, interdisciplinarity, geographic dispersion, and cross-national cooperation, but are too abstract and too far afield from knowledge production contexts to meaningfully analyze key social structures, processes and relationships central to collaborative scientific work. Qualitative analyses detail precisely such social processes and relationships, asking mainly why and how collaboration takes place. These apparently simple questions are difficult to answer. By reflecting on the meaning of scientific collaboration, this paper aims to help develop collaborative opportunities along the Danube region.

Introduction

Scientific collaboration is on the rise. Examinations of the 2.4 million scientific articles produced by the top 110 US universities between 1981-1999 reveals that research team size increased by 50% during this period (Adam, et. al., 2005). This trend accelerates over time from a 2.19% annual rate of growth in the 1980s to a 2.57% rate in the 1990s (an acceleration factor of 17%). Average distance between collaborators also increased, with the annual rate of growth of average miles between collaborators within US universities rising from 3.53% in the 1980s to 4.45% in the 1990s. During this same period rates of collaboration between US and foreign universities increased five-fold. Similarly, analyses of 19.9 million articles collected by *Web of Science* (1955-2000) indicate that team size increased in 99.4% of science and engineering subfields (Wutchy et. al., 2007). Similar numbers are available for Europe (Mattson et. al., 2008). Clearly, scientific collaborations are getting bigger and more international.

These quantitative studies do indicate a rise in collaboration, but leave unexplored the reasons for this increase and the precise character of the collaborations, begging many questions (Vermeulen et. al., 2013). One study suggests that the acceleration of collaboration has been made possible by a sharp decline of the costs of collaboration[1], but is that the only reason, or might the character of scientific questions, their subject matter or the technologies employed also be of influence? Moreover, is the increase driven by purely scientific motives, or do societal developments or so called grand challenges? What can the tendency to collaborate within the European Union tell us? Are we witnessing cultural proximity at work, or can the preference for intra European collaboration be explained by patterns of research funding?

In short, scientific collaboration is increasing – but *why*? And *how*? As Hackett (2005) points out, 'These deceptively simple questions have elicited and qualified answers' (p. 668). This paper aims to answer these questions by giving an overview of the more qualitative study of collaboration, starting with the development of 'big science' towards more contemporary studies of scientific collaboration.

Big Science

The history of science shows a shift from single-investigator 'little science' to increasingly large, expensive, multinational, interdisciplinary and interdependent 'big science'. The origin of the term big science lies in the United States where Physicist Alvin Weinberg coined the term in 1961, while the concept was further developed by historian of science Derek de Solla Price in his book Little Science, Big Science (1963). Their work is part of a pile of books with the term 'big' in the title that all address growth as a distinctive phenomenon of modern society, covering big business, big government, big democracy, big school, big machine, big foundations and big cities.[1] Like all these 'big books', Weinberg and De Solla Price write about increasing dimensions full of wonder and admiration, but at the same time evaluate them critically. Growth is described as part of progress and an inevitable exponent of modern industrial society, while it is also seen as a source of problems. Thereby the books on bigness breath the ambivalence of the modern condition: "To be modern is to find ourselves in an environment that promises us adventure, power, joy, growth, transformation of big ourselves and the world – and, at the same time, that threatens to destroy everything we have, everything we know, everything we are" (Berman, 1983, p. 15). Accordingly, from its emergence the concept of big science has an ambivalent understanding of growth that is characteristic for the modern condition and which is still very much visible in the two opposing views on big science in the debate on big biology.

Besides being normative, big science also developed an empirical side, starting with De Solla Price's book that studies transformation in science. Originally a physicist, Price became interested in the history of science and the annual expansion of the Philosophical Transactions of the Royal Society triggered his fascination for what he later would call big science: "the piles made a fine exponential curve against the wall, I (…) discovered that exponential growth, at an amazingly fast rate, was apparently universal and remarkably longlived" (Price, 1986: 18). This stimulated his work on the quantitative measurement of scientific development and scientometrics (Garfield, 1984). In addition to big science being a quantitative empirical phenomenon, the concept is connected to qualitative studies of scientific transformation. Against the background of the development of Science and Technology Studies, big science has been used to look into historic and contemporary practices of research collaboration. Detailed case studies of different forms of big science in fields as diverse as astronomy, ecology, physics and space research enriched the empirical understanding of big science (Galison & Hevly, 1992). The emergence of large-scale research complexes is perceived as a broader trend and common features are not only found in growing numbers but also in large, expensive instruments, industrialisation, centralisation, multi-disciplinary collaboration, institutionalisation, science-government relations, cooperation with industry, and internationalisation.

As a result, the big science concept should be seen as a historic concept that was formed in the 1960s to reflect on increasing dimensions in science, while acquiring different meanings over time: the big science concept has an empirical as well as an evaluative side. Moreover, when looking at big science empirically, a division can be made between a quantitative and a qualitative perspective and when using the concept to evaluate, positive as well as negative views on big science can be distinguished. Remarkably, discussions on big biology do not reflect on these different meanings, nor use the empirical side of the concept to investigate what kind of transformations actually take place in biology. This disconnection results into an exclusive concern with the attributes of bigness, drawing attention away from "the more significant and interesting question of how science becomes larger" (Capshew and Rader, 1992: 4). It is this process of making science big that I have called the 'supersizing of science' (Vermeulen, 2009).

The History of Scientific Collaboration

In line with the work of Weinberg, physics research around World War II is generally seen as the exemplary situation for the big science concept (Capshew & Rader, 1992; Galison & Hevly, 1992; Nauta, 1984; Weinberg, 1967). However, it is possible to date big science practices back earlier than World War II. Historians of science frequently name astronomy with its large telescopes and observatories as the earliest form of big science (Capshew & Rader, 1992; Price, 1963; Smith, 1992). Price also presented the origins of big science in astronomy:

> [T]he great observatories of Ulugh Beg in Samarkand in the fifteenth century, of Tycho Brahe on his island of Hven in the sixteenth century, and of Jai Singh in India in the seventeenth century each of which absorbed sensibly large fractions of the available resources of their nations. (Price, 1963: 4)

Building on this, historian of astronomy Robert Smith observed that the use of larger telescopes in the nineteenth century and the consequent demands of construction, maintenance, administration, and finance brought a social process of rationalisation and an industrial organisation model (Smith, 1992). With leaders in the research community instituting an increasingly differentiated and hierarchical division of labour within the astronomical workforce (Capshew & Rader, 1992).

In addition, historical observations discard the dominance of large instruments in big science, as large-scale projects with a complex infrastructure are also described as big science. For instance, the grand alliance between science and exploration in the 17th century is a source of big science constellations:

> In 1761 and again in 1769 scientists from England, France and several other countries put together expeditions to observe the transit of Venus across the face of the sun in order to refine measures of solar parallax. These endeavours required major investments in equipment and logistical support

> and contributed to the evolution of an international community of scientists. (Capshew & Rader, 1992: 21)

Infrastructural developments to transport people and information were crucial in this form of big science. Natural historians, for instance, were able to collect more information with the help of research assistants in the field, and both Linnaeus and Darwin were embedded in extensive correspondence networks. In addition, large-scale topographical projects, such as the British 'Magnetic Crusade', created a worldwide network of geomagnetic observatories in the 1830s that were part of this category of big science.

So in contrast to the centralized mode of big science that can be found in the concentration around big instruments that we know from physics, big science can also entail horizontal integration – consisting of scattered sites of inquiry connected through a network of transport and communication infrastructure.

The search for the historic roots of big science practices also sheds new light on the origins of big physics: "If we seek the origins of Big Science in physics, we must look to the period between the two world wars" (Seidel, 1992: 21). It is argued that big physics emerged in California where universities such as Stanford, Caltech and UC Berkeley became involved in the problems of power production and distribution (Galison, 1992; Galison & Jones, 1998). In the 1930s Lawrence's Radiation Laboratory in Berkeley became the centre of energy research, housing the first cyclotron, according to the Rockefeller foundation: "a mighty symbol, a token of man's hunger for knowledge" (Galison 1992: 3). This laboratory grew into a national and international centre of nuclear science, where physicians, biologists, chemists and engineers worked together on the cyclotron to manufacture substances and propagate beams for use in experiments and therapy. Radar, counter-radar and atom projects would spread the Californian big science mode of working to the rest of the United States.

This context of energy research also shows industrial collaboration in big science constellations (Galison 1992; Galison & Jones, 1998). Resources for research on energy and microwave technology not only came from the federal state, the state of California and a philanthropic organisation like the Rockefeller Foundation but also from industry. Apart from particular merits of public-private cooperation, studies of industrial collaboration within big science also reveal several concerns, such as secrecy and the fixation on patenting. The character of research started to change: "instead of exploring new phenomena, the physicists found themselves increasingly spending their time searching for ways to pursue patentable ideas" (Galison, 1992: 4). Although in World War II extensive government investments in research offered an alternative to private financing and the patenting business, this again brought restrictions on disclosure for reasons of national security and limits placed by technological needs of the armed forces.

Post-war science in the United States very much continued in the spirit of World War II experiences (Galison, 1997). The WW II weapon projects became symbols for the future of physics research and other scientific fields:

> "[T]he war trained academic physicists to think about their research on a new scale, invoking a new organizational model (…)The Manhattan Project was far more than an indicator of the usefulness of physics; it was a prescription for the orchestration of research (Galison, 1997: 305-309).

Similarly, big physics entered the stage in Europe with the establishment of the European Organization for Nuclear Research (CERN) in Geneva in 1953 (Pestre & Krige, 1992). In addition, space science expanded in the context of World War II and the Cold War that followed (Graham, 1992; NRC Committee on Solar-Terrestrial Research, 1994). Radar and missile projects built on early large-scale explorations of space. In the context of the 'space race' the United States initiated the Apollo programmes that became institutionalised in the National Aeronautics and Space Administration (NASA) in 1958. These endeavours were mirrored by similar ones in the Soviet Union as well as in Europe.

This new way of organising research was envisioned to extend to other scientific fields, like chemistry, biology and medicine (Price, 1963; Galison, 1997). Consequently, recent research presents detailed case studies of different forms of big science in fields as diverse as astronomy, ecology, physics and space research and enriched the empirical understanding of big science (Bocking, 1997; Crease, 1999; Galison, 1997; Hoddeson et al., 1993; Kwa, 1987; Lambright, 1998; Schloegel and Rader, 2005). In sum, the emergence of large-scale research complexes became perceived as a general trend and although scientific fields have their own characteristics, they can be presented as different forms of big science.

Studying Collaboration

Science studies scholars have adopted varying definitions and approaches for conceptualising and researching scientific collaboration (Parker, et. al., 2010; Vermeulen, et. al., 2013). The notion of 'co-laboring' can be seen as the literal roots of collaboration (Maienschein, 1993). Definitions of scientific collaboration vary, from broad definitions involving some form of co-working, to more delimited definitions requiring teamwork with shared goals –'such as formulating or testing particular empirical hypotheses'- and products, 'such as co-authored papers' (Griesemer & Gerson, 1993: 185). Similarly, scientific collaborations can be delimited to scientists and scientific goals, but it can also involve non-scientists or extend beyond scientific goals. Moreover scientific collaboration can be informally organised or firmly institutionalised: 'an institution for conducting 'big' science – work that involves coordinating many people and substantial resources for long periods of time' (idem: 202). Hackett's definition provides a productive middle-ground that combines a broad scope with an explicit focus both on the cooperative nature of the enterprise and the types and nature of the resources they form to exchange: 'collaboration is a family of purposeful working relationship between two or more people, groups, or organisations. Collaborations form to share expertise, credibility, material and technical resources, symbolic and social capital' (Hackett, 2005: 671).

Most of the studies that define and describe scientific collaboration are based on investigations of physics or space research. They study for instance an organisation like CERN in Geneva, where large-scale instruments are built to detect the very substance of matter: sub-atomic particles. As these so-called detectors are very big, single institutes or nations are unable to afford their construction, requiring collaboration. Similarly, space research concentrates around large-scale technology, and requires a centralised, hierarchical and tightly integrated organisational structure for successful execution. While a large body of research in science studies has demonstrated the centrality of systems and technologies for the organisation of collaboration, a concise and coherent narrative on collaboration in the life sciences remains absent. Nevertheless, the existing literature offers valuable insights. While acknowledging the complexity of the phenomenon and noting the relative lack of qualitative studies, they advance various approaches for collaborating, reasons for doing so, as well as considering the structures in which collaborations occur.

Reasons for scientific collaboration vary. The development of large, fabulously expensive instruments are a reason to share costs and collaborate. Other motives include the need for complementary specialties or disciplines, as well as pressure for societal relevance, decreasing travel and communication costs, and to increase scientific credibility at the level of the project or even discipline. Research has also demonstrated the importance of strong interpersonal relationships and deep emotional commitments to the group and its ideas for motivating and structuring collective scientific work. Additionally, collaboration can be stimulated by funding incentives, political motivations, or simply because it is viewed as good in and of itself. Overall, collaboration is driven by a variety of purposes and reasons, at least some of which are ubiquitous across disciplines.

Structures of scientific collaboration also vary. Shrum, Chompalov and Genuth (2007) distinguish four different ways to structure collaboration on the basis of their mix-methods study of 53 multi-institutional collaborations in particle physics, space sciences, and allied disciplines. Bureaucratic collaborations have a hierarchical authority structure, written rules and regulations, formalised responsibilities, and a specialised division of labour, while leaderless collaborations are similarly formal but do not have a designated scientific leader and lack hierarchical management. In contrast, non-specialised collaborations have designated scientific leaders and are hierarchically managed, but are less formalised and differentiated than bureaucratic collaborations. Finally, participatory collaborations are highly egalitarian, with participatory and consensual decision-making, no formal organisational structure, and limited regulatory powers among scientific leaders. This last type is typical of particle physics, while the other types were found to exist across the investigated disciplines.

Sociologist of science Knorr-Cetina (1999) compared collaborative practices in high-energy physics and molecular biology during the 1980s, concluding that in opposition to the large transnational collaborations of physics, biology is an individual centred, non-collaborative science. However, in the 1990s several studies on the Human Genome Project began foregrounding collaboration in biology. The Human Genome Project was often viewed as the first true large-scale collaboration in biology, giving rise to a variety of publications discussing issues related to collaboration such as structure, data exchange, and public-private competition (Cook-Deegan, 1994; Hilgartner, 1995; Sloan, 2000; Venter, 2007). Peter Glasner (1996) used the term 'co-laboratory' to indicate that the project was built of different international laboratories working together to produce the human genome sequence. The Human Genome Project also gave rise to debates about the benefits and demerits of collaboration, including arguments that large-scale projects can industrialise, bureaucratise and politicise research, potentially diluting scientific autonomy, creativity, and job satisfaction. To illustrate, genome sequencing was portrayed as "massive, goal-driven and mind-numbingly dull" (Roberts, 2011: 1183). These debates reflect more general critical approaches to collaboration, which can be difficult, time consuming, and impose substantial coordination and communication costs (Cummins & Kiesler, 2005; Katz & Martin, 1997).

Finally, increasing scales of research go beyond the natural sciences as large-scale networks are increasingly proliferating in the social sciences and humanities as well (Dormans, 2009; Dormans & Kok, 2010). The integration of information technologies stimulates large-scale research projects in sociology, while an example of big history can be found in the large-scale research project 'Tensions of Europe', which explores and defines ways to study transnational European history. [2]

Conclusions

Cooperation in the Danube Region is a very special endeavour as it combines local, with international scientific collaboration. While having local proximity as an incentive, collaboration along the river Danube also crosses borders, mixing both modes into regional collaboration. In line with the recognition of different types of collaboration, this paper reflected on the study of scientists working together in order to come to a deeper understanding about what scientific collaboration is and what it entails. The Humboldt-Kolleg Belgrade 2013 Resources of Danubian Region: the Possibility of Cooperation and Utilisation already showcasted a variety of examples of existing collaborations in the region, from physics, to astronomy, life sciences and cultural studies. As in the history of scientific collaboration, reasons to collaborate also vary in the Danube region as well as the organisational formats that have been applied. In order to further strengthen Danubian scientific collaboration, it may help to reflect more on the different reasons to collaborate in the region, and asking which organisational formats fit the purpose best. It is key to build on experience and capacity, studying and exchanging best practices, while also taking the time to develop new initiatives. Thereby it is best to also involve policymakers and funding organisations in the setting up and expansion of collaboration in the Danubian region.

1. See Fay, C. N. (1912). *Big business and government*. New York: Moffat, Yard & Co; Hendrick, B. J. (1919). *The age of big business: a chronicle of the captains of industry*. New Haven: Yale University Press; Drucker, P. F. (1947). *Big business*. London & Toronto: W. Heinemann; Pusey, M. J. (1945). *Big government: can we control it?* New York & London: Harper & Bros; Appleby, P. H. (1945). *Big democracy*. New York: Knopf; Barker, R. G. & Gump, P.V. (1964). *Big school, small school*. Stanford, CA: Stanford University Press; Rogers, D. (1971). T*he management of big cities; interest groups, and social change strategies*. Beverly Hills, CA: Sage publications; Nielsen, W. (1972). *The big foundations*. New York: Columbia Press; Jungk, R. (1968). Big machine. New York: Scribner.
2. Retrieved November 2, 2008 from http://www.tensionsofeurope.eu

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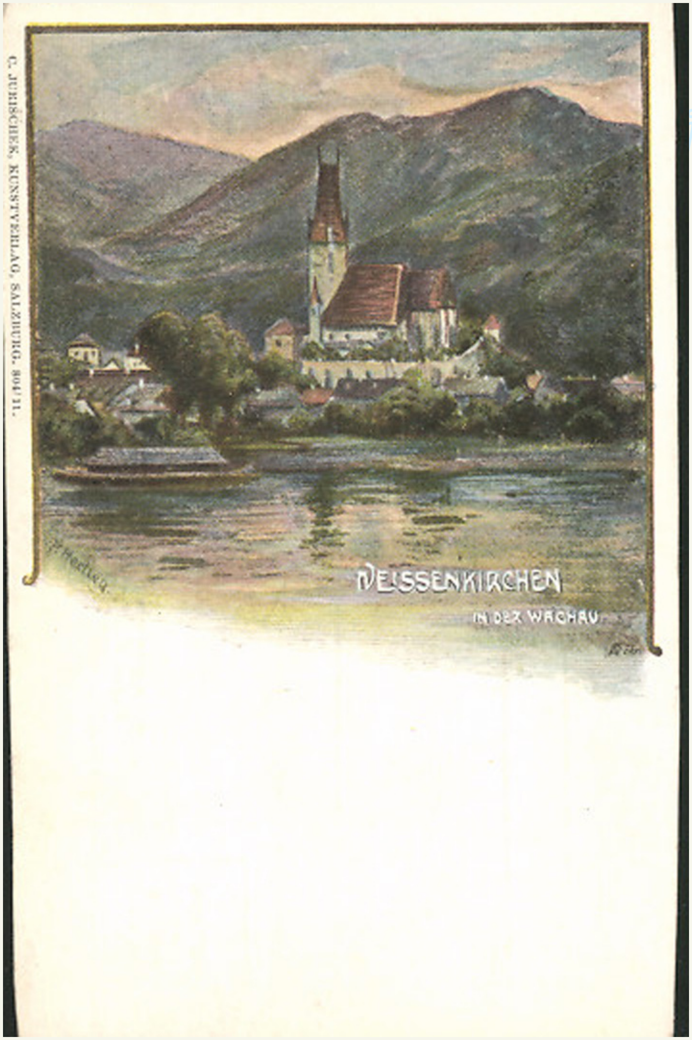
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