

EMPIRICAL METHODS IN AL-BIRUNI'S KITAB AL-JAMAHIR AND AL-ATHAR AL-BAQIYA

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Abstract. *The article examines empirical methods in Abu Rayhan al-Biruni's "Kitāb al-Jamāhir fī ma'rifat al-jawāhir" and "Al-Āthār al-bāqiya 'an al-qurūn al-khāliya". Kitab al-Jamahir is analyzed through mineralogical observation, classification of precious stones, specific weight, material properties, and practical testing, while Al-Athar al-Baqiya is examined through time reckoning, calendar systems, ancient chronologies, historical reports, and comparative source criticism. The study shows that observation, measurement, comparison, classification, calculation, verification, and critical treatment of sources were interconnected in Al-Biruni's scholarly practice.*

Keywords: *Al-Biruni, Kitab al-Jamahir, Al-Athar al-Baqiya, empirical method, mineralogical observation, specific weight, chronology, calendar, source criticism, medieval science*

Annotatsiya. *Maqolada Abu Rayhon Beruniyning "Kitāb al-Jamāhir fī ma'rifat al-jawāhir" va "Al-Āthār al-bāqiya 'an al-qurūn al-khāliya" asarlarida empirik metodlarning qo'llanishi tahlil qilinadi. "Kitab al-Jamahir" mineralogik kuzatuv, qimmatbaho toshlar tasnifi, solishtirma og'irlik, modda xossalari va amaliy tajriba nuqtayi nazaridan, "Al-Athar al-Baqiya" esa vaqt hisobi, taqvimlar, qadimgi xalqlar xronologiyasi, tarixiy rivoyatlar va qiyosiy manbashunoslik*

jihatidan o'rganiladi. Natijalar Beruniy ilmiy metodida kuzatuv, o'lchov, solishtirish, tasniflash, hisob-kitob va manbani tanqidiy tekshirish o'zaro bog'langanini ko'rsatadi.

Kalit so'zlar: *Beruniy, Kitab al-Jamahir, Al-Athar al-Baqiya, empirik metod, mineralogik kuzatuv, solishtirma og'irlik, xronologiya, taqvim, manbashunoslik, o'rta asr fani*

Аннотация. В статье анализируется применение эмпирических методов в трудах Абу Райхана Бируни "Kitāb al-Jamāhir fī ma'rifat al-jawāhir" и "Al-Āthār al-bāqiya 'an al-qurūn al-khāliya". "Kitab al-Jamahir" рассматривается с точки зрения минералогического наблюдения, классификации драгоценных камней, удельного веса, свойств вещества и практического опыта. "Al-Athar al-Baqiya" изучается через исчисление времени, календарные системы, хронологию древних народов, исторические предания и сравнительное источниковедение. Результаты показывают, что в научном методе Бируни наблюдение, измерение, сравнение, классификация, расчет и критическая проверка источников были взаимосвязаны.

Ключевые слова: *Бируни, Kitab al-Jamahir, Al-Athar al-Baqiya, эмпирический метод, минералогическое наблюдение, удельный вес, хронология, календарь, источниковедение, средневековая наука*

INTRODUCTION. Abu Rayhan al-Biruni's scientific legacy is important not only because of the range of subjects he investigated, but also because of the methods through which he transformed scattered information into ordered knowledge. His Kitāb al-Jamāhir fī ma'rifat al-jawāhir and Al-Āthār al-bāqiya 'an al-qurūn al-khāliya represent two different intellectual fields: the first deals mainly with minerals, precious

stones, metals, material properties, and practical testing; the second deals with time, calendars, eras, religious festivals, historical memory, and chronological comparison. Yet these two works are methodologically connected. Both show that Al-Biruni did not treat knowledge as mere transmission from earlier authorities; he tested, compared, classified, calculated, and corrected.

The relevance of the topic lies in the need to interpret medieval empirical method more carefully. Empirical method in Al-Biruni's context should not be reduced to modern laboratory experiment. It also included observation of visible properties, comparison of data, measurement of weight and density, classification of objects, verification of reports, correction of inherited information, and source criticism. In *Kitab al-Jamahir*, empirical method appears in the study of material objects. In *Al-Athar al-Baqiya*, it appears in the ordering of historical time and the comparison of traditions.

Kitab al-Jamahir is significant for the history of mineralogy because it shows how the properties of stones were investigated through observation and practical testing. The analyzed literature indicates that Al-Biruni objected to classifying gems only by color and treated specific gravity, brilliance, and hardness as more reliable properties [Sparavigna, 2013, p. 9]. *Al-Athar al-Baqiya* is equally important for the study of empirical reasoning in the humanities. At the beginning of the work, Al-Biruni states the need to proceed from what is known to what is less known, to collect traditions from those who report them, and to correct them as much as possible [Sachau, 1879, p. 4]. This methodological statement makes the work not merely a chronicle of ancient peoples, but a source-critical investigation of time and historical memory.

The main research question of this article is: how do empirical methods appear in Al-Biruni's *Kitab al-Jamahir* and *Al-Athar al-Baqiya*, and what do these methods reveal about observation, measurement, comparison, classification, verification, and source criticism in medieval science? The aim is to analyze these two works comparatively as sources for reconstructing natural-mineralogical and historical-chronological forms of empirical reasoning.

METHODS. The research is based on historical-analytical, comparative, source-critical, contextual, and conceptual methods. The historical-analytical method makes it possible to interpret both works within medieval scientific culture rather than through anachronistic assumptions about modern laboratory science. The comparative method is used to identify similarities and differences between the empirical procedures of *Kitab al-Jamahir* and *Al-Athar al-Baqiya*. The source-critical method is applied to examine how Al-Biruni treated earlier authorities, oral reports, material evidence, and numerical data.

The key analytical concepts are “empirical method”, “observation”, “measurement”, “classification”, “verification”, “source criticism”, “mineralogical observation”, “chronological comparison”, “historical observation”, and “medieval scientific reasoning”. In this article, empirical method refers to a system of inquiry in which information is not accepted passively, but is checked through observation, comparison, measurement, calculation, or critical evaluation of sources.

The two works are compared according to seven criteria: object of investigation; type of evidence; form of observation; role of measurement and calculation; method of comparison; degree of classification; and transformation of empirical evidence into scholarly conclusion. *Kitab al-Jamahir* is analyzed as a source for material observation and practical

testing, while Al-Athar al-Baqiya is analyzed as a source for chronological calculation and historical verification. The sources used in the article were selected according to thematic relevance, bibliographic clarity, and the availability of exact page references.

RESULTS. The first result of the analysis is that Kitab al-Jamahir presents empirical reasoning through the material study of minerals and precious stones. Al-Biruni did not limit mineralogical knowledge to naming stones or repeating received descriptions. The source material reveals that his attention was directed to observable and comparable properties such as color, transparency, hardness, weight, and physical behavior under testing. In one example, diamond is described as superior in hardness because it scratches ruby, while ruby scratches stones below it but cannot scratch diamond [Abed, 2003, p. 4]. This is not a purely literary statement; it reflects a practical method of comparing hardness through physical action.

A second empirical element in Kitab al-Jamahir is the measurement of specific weight. The sources indicate that Al-Biruni used hydrostatic methods to determine the specific gravity of minerals. A vessel was filled with water, a mineral was inserted, and the displaced water was measured; the weight of the mineral was then compared with a standard volume of ruby [Abed, 2003, p. 4–5]. Sparavigna describes a similar procedure in which the vessel was filled until water flowed out through a side pipe, after which the mass of the substance and displaced water allowed the density to be determined [Sparavigna, 2013, p. 9]. This shows that Al-Biruni's mineralogical method moved from qualitative description to quantitative comparison.

A third element is classification. Al-Biruni's classification of stones was not based only on external appearance. He treated color as

insufficient because visually similar stones could differ in hardness, brilliance, and specific weight [Sparavigna, 2013, p. 9]. The available evidence shows that, for example, weights of different stones were compared relative to a fixed ruby standard: ruby core, spinel, pearl, agate, and quartz were placed within a comparative numerical framework [Abed, 2003, p. 5]. Such classification transformed mineralogy into a measurable discipline.

A fourth element is practical testing. *Kitab al-Jamahir* preserves evidence of thermal examination of stones. In a reported case, stones brought from India were heated; one pure red stone preserved its color, while another lost its color and changed in appearance. The conclusion was that the stone losing its color could not be true ruby [Abed, 2003, p. 6–7]. This example is important because the authenticity of a stone is not judged by reputation or name, but by its physical behavior under controlled practical conditions.

A fifth empirical feature is the link between mineralogical knowledge and social practice. *Kitab al-Jamahir* was not only a theoretical text for scholars. The study of genuine and imitation stones had direct relevance for merchants, jewelers, assayers, and treasury officials. Kuranbaeva notes that Al-Biruni's treatise was connected with the practical task of distinguishing genuine metals and precious stones from counterfeits [Kuranbaeva, 2024, p. 34]. The same study reports that the device associated with Al-Biruni for distinguishing genuine and counterfeit metals and stones has not survived, but that necessary information about the "Biruni vessel" was recorded in the relevant text [Kuranbaeva, 2024, p. 36]. Thus, empirical method served both scientific and practical-economic needs.

A sixth result concerns tabulation and transmission. Kuranbaeva states that Al-Khazini used Al-Biruni's calculations and that Al-Biruni presented the results of his relative-gravity measurements in tables [Kuranbaeva, 2024, p. 36]. Abattouy's discussion of Islamic weights and balances also shows that Al-Khazini's *Book of the Balance of Wisdom* transmitted mechanical and balance-related traditions, including materials connected with Al-Biruni [Abattouy, 2006, p. 9]. This suggests that the empirical results of *Kitab al-Jamahir* and related treatises were not isolated observations, but became part of a broader scientific tradition of measurement.

Al-Athar al-Baqiya represents a different form of empirical reasoning. Its object is not stone, metal, or material substance, but time, memory, and historical report. Nevertheless, the method is deeply empirical in the medieval sense. Al-Biruni begins by defining a procedure for gathering traditions, correcting them, and moving from the known to the less known [Sachau, 1879, p. 4]. This statement provides the methodological basis of the work: historical knowledge must be collected, compared, corrected, and arranged.

The second empirical feature of *Al-Athar al-Baqiya* is chronological comparison. Al-Biruni compares solar, lunar, and lunisolar systems. He records that certain groups used a solar year close to 365 1/4 days [Sachau, 1879, p. 12], while Hebrews, Jews, Sabians, and Harranians used an intermediate system deriving the year from the Sun and the months from the Moon [Sachau, 1879, p. 13]. The work also discusses Arab intercalation and the borrowing of intercalary practices from Jewish systems [Sachau, 1879, p. 14]. This is a comparative method applied to time-reckoning systems.

The third empirical element in *Al-Athar al-Baqiya* is the use of a universal measure. Al-Biruni explains that intervals between epochs should be measured by days, since days are counted in the same way by all nations [Sachau, 1879, p. 72]. He later develops rules for reducing different eras to one another through the concept of *Dies Paratae* [Sachau, 1879, p. 140]. This converts historical memory into a calculable system. Time becomes a measurable framework through which different traditions can be synchronized.

The fourth element is the correction of inherited or traditional claims by astronomical observation. Al-Biruni distinguishes between conjunction times determined by astronomical observation and those obtained by the rules of religious chronologers; he advises the use of tables based on corrected observations [Sachau, 1879, p. 151]. He also states that certain distances involved in observing the new moon cannot be ascertained except by experiment [Sachau, 1879, p. 178]. These passages show that *Al-Athar al-Baqiya* gives priority to observation and calculation over purely inherited chronological rules.

The fifth empirical feature is source criticism. Al-Biruni compares conflicting religious and historical reports and treats disagreement itself as a reason for investigation. For instance, different textual traditions give different numbers for the interval from Adam's expulsion from Paradise to Noah's flood: 1,656 years, 2,242 years, and 1,307 years [Sachau, 1879, p. 22]. Rather than harmonizing these numbers artificially, Al-Biruni preserves the discrepancy and makes it a matter of critical comparison. In another passage, he rejects blind following among religious communities when discussing uncertain chronological claims [Sachau, 1879, p. 76]. This is source criticism in a medieval form.

The common empirical features of both works can now be identified. Both rely on observation; both compare evidence; both classify information; both verify inherited claims; both correct earlier reports where possible. In *Kitab al-Jamahir*, the evidence is material and physical: stone, metal, weight, hardness, heat, water, and density. In *Al-Athar al-Baqiya*, the evidence is chronological and historical: era, calendar, festival, tradition, textual report, astronomical cycle, and numerical interval. The difference lies in the object, not in the underlying intellectual discipline.

DISCUSSION. Al-Biruni's empirical methods should not be equated fully with modern laboratory science. *Kitab al-Jamahir* does not represent modern geology, and *Al-Athar al-Baqiya* does not represent modern academic historiography in the institutional sense. Yet both works reveal historically grounded forms of empirical reasoning. They show how a medieval scholar could test claims against observation, organize information through classification, and correct inherited material through calculation and comparison.

In *Kitab al-Jamahir*, empirical reasoning is formed through the direct engagement with material objects. A stone is observed, compared, weighed, heated, scratched, classified, and evaluated. This procedure is important because mineralogical names and colors could mislead. A red stone might appear to be ruby, but heat, hardness, or specific weight could reveal otherwise [Abed, 2003, p. 6–7]. Therefore, Al-Biruni's method does not depend on appearance alone; it seeks stable properties that can be compared.

In *Al-Athar al-Baqiya*, empirical reasoning is formed through chronological comparison and historical verification. A date, era, festival, or religious report is not accepted merely because it belongs to a respected

tradition. It is compared with other systems, reduced to days, checked against astronomical cycles, and placed within a broader chronological framework. When Al-Biruni asks how one can believe something contrary to what is evident to the senses, he gives a clear expression to his preference for observable evidence over unsupported claims [Sachau, 1879, p. 8].

The difference between the two works is therefore methodological in application, not in principle. *Kitab al-Jamahir* treats the physical world as the field of verification. *Al-Athar al-Baqiya* treats historical time as the field of verification. In the first, the instrument is the balance, vessel, heat, and comparative hardness test; in the second, the instrument is the calendar table, astronomical observation, numerical interval, and comparison of traditions. Both works transform scattered information into ordered knowledge.

The source-critical significance of *Kitab al-Jamahir* lies in its value for the history of mineralogy, material culture, trade, medicine, craft knowledge, and economic regulation. The study of genuine and counterfeit stones was not only scientific; it also had practical consequences in the marketplace and treasury. The source-critical significance of *Al-Athar al-Baqiya* lies in its value for chronology, calendar studies, comparative religion, historical memory, and medieval historiographical method. It shows how time could function as an instrument of historical verification.

There are limitations. The identification of medieval mineral names with modern geological terms is difficult and requires caution. A medieval term may refer to a group of stones, a color category, a trade name, or a culturally defined object rather than a modern mineral species. Similarly, medieval calendar terminology cannot be modernized

without careful source criticism. The interpretation of Al-Athar al-Baqiya must consider translation, manuscript transmission, and the difference between Al-Biruni's own observation and inherited reports. The earliest illustrated manuscript tradition of Al-Athar al-Baqiya is also later than the original composition, reminding the researcher that transmitted texts are historically mediated [Zajac, 2007, p. 84].

Nevertheless, the two works remain exceptional sources for reconstructing empirical reasoning in medieval science. They show that empirical method was not limited to natural science. In Al-Biruni's practice, mineralogy, chronology, history, religion, trade, and astronomy could all be treated through procedures of observation, comparison, measurement, correction, and critical judgment.

CONCLUSION. Kitab al-Jamahir and Al-Athar al-Baqiya together reveal two complementary forms of Al-Biruni's empirical method – the natural-mineralogical and the historical-chronological – for while the first investigates material objects, the second turns to time, memory, and historical tradition. In Kitab al-Jamahir the empirical method manifests itself through the observation of colour, hardness, transparency, weight, specific gravity, and the physical behaviour of substances under testing, its defining methodological feature being the movement from external appearance toward measurable property. In Al-Athar al-Baqiya, by contrast, the same method takes the form of chronological comparison, calendar conversion, the correction of received traditions, numerical calculation, and astronomical observation, so that its central characteristic becomes the transformation of historical memory into a verifiable temporal system. In both works the reliability of knowledge rests not upon authority alone but upon comparison, verification, measurement, calculation, classification, and cautious

judgement – clear evidence that Al-Biruni's method fused natural observation with source criticism. Taken together, these writings are of considerable importance for the history of mineralogy, chronology, calendar studies, comparative religion, material culture, and medieval scientific methodology; and future research might profitably concentrate on the comparison of manuscripts, on terminology, on the digital mapping of chronological data, and on the relationship between Al-Biruni's empirical practices and other medieval scientific traditions.

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