

Analysis of al-Biruni's Contribution to Paleontology, Sedimentology and Mineralogy

BITARA

Volume 5, Issue 1, 2022: 145-155
© The Author(s) 2022
e-ISSN: 2600-9080
<http://www.bitarajournal.com>
Received: 24 February 2022
Accepted: 28 February 2022
Published: 24 March 2022

Hifdzi Zaim Zamri,¹ Roziah Sidik @ Mat Sidek,^{1,2*}
Wan Nasyrudin Wan Abdullah^{1, 3} & Habibah Jamil⁴

1 Institute of Islam Hadhari, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi Selangor Malaysia

2 Research Centre for Arabic Language and Islamic Civilization, Faculty of Islamic Studies, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi Selangor, Malaysia

3 Research Centre for Quran and Sunnah, Faculty of Islamic Studies, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi Selangor, Malaysia

4 Geology Programme, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi Selangor, Malaysia

Email: hifdzizaim06@gmail.com; roziah@ukm.edu.my; tokwed@gmail.com; bib@ukm.edu.my

* Corresponding Author: roziah@ukm.edu.my

Abstract

Abu Raihan Muhammad Bin Ahmad or better known as al-Biruni is a renowned polymath Islamic scholar. His contribution towards the development of science was so profound. Unfortunately, his contribution is not well known in the history of the development of geological studies as compared to the European geologist such as Leonardo da Vinci, who some considered the first known geologist of all time. The focus of this study is to analyze al-Biruni's contribution in the development of geological studies especially towards the modern understanding in the field of geology. The approach that has been used in this study is through qualitative studies by analyzing research that have been done in the past. Results of this study shows the contribution of al-Biruni in his findings that are much aligned with modern understanding towards geology particularly in paleontology, sedimentology and mineralogy. This study also concludes that al-Biruni is an Islamic polymath scholar in the 10th century and has preceded later European geologist in developing and making an impact towards the understanding of geology today.

Keywords: Al-Biruni, Geology, History of Science, Islamic Civilization, Golden Age of Islam

Cite This Article:

Hifdzi Zaim Zamri, Roziah Sidik @ Mat Sidek, Wan Nasyrudin Wan Abdullah & Habibah Jamil. 2022. Analysis of al-Biruni's Contribution to Paleontology, Sedimentology and Mineralogy. *BITARA International Journal of Civilizational Studies and Human Sciences* 5(1): 145-155.

Introduction

'Geology' is described as the study of Earth, its interior and its exterior surfaces, the minerals, rocks, other materials that are around us, and the processes that have resulted in the formation of those materials (Earle, 2014). The history of the geology has been known to begin during the Middle Ages although some consider it as a time that there was no interest in geology (Clarke, 2007). Without neglecting the findings and contribution towards the development of geology of European geologist at that time, it is unfortunate that Muslim scholars during the golden age of Islam have not been highlighted on their contribution towards the development of geology.

The golden age of Islam was time that lasted nearly five centuries, beginning with the reign of Abbasid Caliph Harun Al-Rashid (786-809) and ended with the collapse of the Abbasid Caliphate because of the Mongol invasions in 1258 CE (Renima et al., 2016). One of the reasons

for term 'The Golden Age' of Islam is because of the advancement in knowledge that has been done by scholars at that time. These advancements in knowledge include science, art, and culture that were studied in detail systematically (Essa & Ali, 2012). Initially, that year has marked Muslim scholars as contributor into the development and advancement in the field of geology.

This study aims to bring forth some remarkable findings and contribution that has been done by a renown Islamic scholar during the Golden Age of Islam that comes by the name of Al-Biruni. The focus towards his contribution is mostly based on acknowledgement that has been given to him by George Sarton, the father of history of science as "one of the greatest scientists in Islam and all considered one of the greatest of all times" (Sparavigna, 2013). This study also aims to analyze the impact of his contribution and findings towards the modern understanding of geology today. The approach that has been used in this study is through qualitative studies by analyzing similar research that have been done in the past.

Methods

The method of this study is implemented through qualitative studies whereby past studies regarding the contribution of Al-Biruni were analyzed specifically in the field of geology. Studies on the development in the geology studies and the understanding of geology today were also analyzed in this study. A deductive analysis has been done to figure out the importance of Al-Biruni's contribution in geology and how it impacts in the current understanding of geology.

Result

History of Geology During the Middle Ages (550-1450)

The Middle Ages also known as the medieval period lasted between the year 550 to 1450 (Johnston, 2011). Although historians recognize this period as a lack of culture and advancement phase in Europe, there are records of findings and development that has been done in this period specifically in the studies of Earth or better known as geology today.

Names like Isidore from Seville (AD 570-636), Vincent de Beauvasi and Bartholomew the Englishman, both in the 13th Century were recorded as people who kept alive the knowledge of geology and developed it from earlier writers (Clarke, 2007). One of the most prominent scholars of geology during this period in the history of geology in Europe is arguably Leonardo Da Vinci (1452-1519). In fact, Reajendran even considered him as the first renaissance geological thinker because of his deep discussion and writings regarding rocks, rivers, fossils in one of his books titled *Codex Leicester* (Rajendran, 2019).

One of Leonardo da Vinci's findings was that he recognized fossil shells as the remaining of once-living organisms and changes had occurred in the relationship between sea and land (Clarke, 2007). Even at that time, many still has doubts on the origin of fossil as he tried to convince his contemporaries that fossils were the remains of organism (Gohau, 1990). His deep interest towards the study of Earth is also portrayed in many of his painting as he

draws detailed landscape of rocks such as the painting called “Virgin of the Rocks” (Rajendran, 2019).

George Bauer also known as ‘Agricola’ (1494-1556) contributed towards the development of geology during the Middle Ages. He contributed towards the advancement of knowledge regarding minerals and metal carrying veins. One of his great works was called ‘De Re Metallica’, which described in an instructive way about mining and metallurgy that was carried out at his time and place (Clarke, 2007).

Life & Works of Abu Raihan al-Biruni (973-1048)

Abu Raihan Al-Biruni was born in Kath, Khwarezm that is located western Central Asia, bordered by Aral Sea and deserts (Sparavigna, 2013). Today, the region of Khwarezm is fractioned into Uzbekistan, Kazakhstan and Turkmenistan. He is better known by his surname ‘Al-Biruni’ which signifies “from the outer district” in Persian because he was born and live in the outer district of Khawarizmi, which is known as a place where outsiders live (Batchelor, 2015).

Al-Biruni came from a modest family of Tajik origin that had no strong educational background. But that did not stop him from learning throughout his age. Since his childhood years, he was taught by a prince of the ruling Banu Iraq named Abu Nasr Mansur, who was also a famous astronomer-mathematician (Batchelor, 2015). Abu Nasr and Al-Biruni maintain a good relationship with one another to an extent that Al-Biruni made some significant findings at a young age (Said, 1992). For instance, Al-Biruni succeeded in calculating the latitude of Kath through observing the maximum altitude of the sun just at the age of 17. By the age of 22, he published a study of his regarding Cartography or a work on map projections (O’ Connor & Robertson, 1999). His early peaceful life learning abruptly ended with the overthrow of the Banu Iraq in a coup in 995.

Because of the coup that happened, Al-Biruni had to leave his homeland and travelled until he settled in a place called Ravy, which is located near Tehran today. There, he met an astronomer named Al-Khujandi, who built a large instrument to observe meridian transits of the sun near the solstices (Batchelor, 2015). Al-Biruni found out that Al-Khujandi’s latitude measuring’s of Kath was inaccurate and gave explanation towards the inaccuracy in one of his books titled, “The Determination of the Coordinate of Locations and for Correctly Ascertaining the Distances between Places” (Sparavigna, 2013). In the year 1004, Al-Biruni returned to Kath and remained in the court of Ali Ibnu Ma’mum, who then ruled Khwarezm followed by his brother, Abu Al-Abbas. Both rulers were considered the generous patrons of science to an extent Abu Al-Abbas sponsored Al-Biruni as a sign of his support for the efforts in constructing an astronomical instrument to observe solar meridian transits that he conducted in 1016 (Batchelor, 2015).

Soon after, Sultan Mahmood of Ghazna took Al-Biruni as a captive among many other scholars during his attack on Kath in the year 1017. During his captivity in Ghaznah, it is said that Al-Biruni’s genius and academy maturity came to full bloom (Ardi, 2016). Al-Biruni conducted astronomical observations in Ghazni as well as the Kabul area and joined Sultan Mahmood in his conquest of India. During this time, he studied many aspects of India and compiled them in one of his books entitled *Kitab Al-Hind* (Sparavigna, 2013).

Al-Biruni is considered as a polymath that mastered many fields of knowledge as an astronomer, mathematician, philosopher, studies physics, and natural science. In all his lifetime, Al-Biruni managed to produce more than 146 titles ranging in a multitude of disciplines, which only 13 of these have been published in modern times (Kenedy, 1970).

al-Biruni's Contribution in Geology

The name of Al-Biruni is barely heard or written in the history of geology especially in the Middle Ages. According to Bobojan Gafurov in his article on the Unesco Courier, even though his contribution is acknowledged as "far ahead of his time", his most brilliant discoveries seemed incomprehensible to most of the scholars of his days" (Gafurov, 1974). It is also arguable that his findings were more advanced in scientific reasoning than his predecessor like Leonardo Da Vinci that came 400 years after his lifetime. Al-Biruni's contribution towards the field of geology can be categorized into 3 sub-branches of geology, namely paleontology, sedimentology, and mineralogy.

Paleontology

Paleontology today is described as a study of the history of life on Earth as based on fossils. During the Middle Ages, the origin of fossils was highly discussed and there were many theories and opinions on what fossils were at that time. Even in the 14th century, many still had doubts about the origin of fossils when Leonardo Da Vinci proposed his theory about it (Gohau, 1990). This debate carried on until it was firmly resolved during the year 1700.

During Al-Biruni's expedition to India, he made some observations and findings about fossils. His findings can be found in one of his books entitled *Kitab Al-Hind*, where he found stones which when broken apart, it would be found containing shells, cowry shells and fish-ear like fossils on the mountains of Himalaya (Sparavigna, 2013). Through this observation, he finally defined fossils as a living creature that once lived millions of years ago (Basya, 2015). From his findings on fossils, Al-Biruni deduced a remarkable conclusion regarding the geological history of mount Himalaya by saying:

This steppe of Arabia was at one-time sea, then was upturned so that the traces are still visible when wells or ponds are dug, for they begin with layers of dust, sand and pebbles, then there are found in the soil shells, glass and bones which cannot possibly be said to have been buried there on purpose. Nay, even stones extracted in which are embedded shells, cowries and what is called 'fish-ears', sometimes well-preserved, or the hollows are there of their shape while the animal has decayed" (Gafurov, 1974).

From his observation and explanation towards fossils above, Al-Biruni also laid some fundamental techniques and steps of how to find, extract and forms fossils that can be found (Basya, 2015). First, it begins by identifying the types of rock that fossils are found, such as layers of dust, sand, and pebbles. Then, it describes the process of extraction and different types of fossils that can be found such as soil shells, glass, and bones. Al-Biruni also recognized

different forms that fossils can be found such as in a form of well-preserved or hollows of the fossil's shape.

Sedimentology

Sedimentology is a study related to the physical and chemical properties of sedimentary rocks and their formation. One of Al-Biruni's contributions in this sub-field of geology is about his findings towards the sedimentary description of the Ganges Basin located in India (Ozcep & Ozcep, 2014). He deduced about the land of India, which was once a sea, and that it later became land through a sedimentary process. He believed that the deposition of detritus from the mountain that the seabed was filled up and became habitable over time (Alavi, 1976). His explanation towards this phenomenon is as follow:

If you consider the rounded stones found in the earth however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current; stones that are of smaller size at a greater distance from the mountains and where the streams flow more slowly; stones that appear pulverized in the shape of sand where the streams begin to stagnate near their mouths and near the sea – if you consider all this you can scarcely help thinking that India was once a sea, which by degrees has been filled up by the alluvium of streams (Salam, 1984).

His findings show how deep understanding he has about how alluvial deposits and how sedimentary transportation happened in the Indus Valley of Ganges Basin even though there was limited knowledge during those time. It has been dated that the earliest attempt of documentation regarding the geology of India was found in 1869, and it has been compiled by T. Oldham. The first three geological maps of parts of India were made in the 19th century (Chakraborty, 1971). However, there is no mention in Al-Biruni's contribution towards his finding about the sedimentology of the Ganges Basin in the early documentation of India's geological study.

Mineralogy

Mineralogy is a study regarding the scientific study of the chemistry, crystal structure and physical (including optical) properties of mineral. During Al-Biruni's time, the classification of gems has already been done but the classification of gems was only limited to the colors of the gem. Al-Biruni objected to the classification of gems only by color and proposed a few more physical properties that can classify types of gems such as the specific gravity, brilliance, density, and hardness (Ansari, 1975).

The hardness of a gem is tested and classified using a tip of sample material and by observing the indentation it is producing (Ansari, 1975). Meanwhile, the specific gravity of a gems is measured by using a specific instrument that he created as shown in Figure 1. The cone-shaped vessel in which the level of oil or water were to remain constant, and any excess of water or oil were to be drained out made to measure the volume of fluid displaced by a gem.

From the help of this apparatus, Al-Biruni was able to measure the displaced water with such accuracy that his findings nearly correspond with modern values. From this experiment, he deduced the principle that the specific gravity of an object corresponds to the volume of water it displaces per unit weight (Batchelor, 2015).



Fig.1. The Apparatus Used to Calculate Specific Gravity of Stones (Ansari, 1975)

All his findings were recorded in a specific book entitled *Kitab al-Jamahir fi Ma'rifat al-Jawahir*. Al-Biruni succeeded in determining the specific gravity of 18 precious stones such as gold, mercury, lead, silver, copper, brass, tin and iron (Ahmad & Baipakov, 2000). For Example, Al-Biruni put the specific gravity of gold at 19.0 and iron at 7.92 (Gafurov, 1974). Al-Biruni's finding in the specific gravity played a vital contribution at his time as it has been benefited by many Islamic countries. One of the reasons why his contribution was important at that time was that he acknowledged the social importance of gems and metals. So, he laid down the fundamental physical properties that can evaluate the quality of gems and metals (Ansari, 1975). Al-Biruni's *Kitab al-Jamahir fi Ma'rifat* was one of the greatest during the golden ages of Islam because he studied gems and metals by the method of empirical studies that soon after inspired many scholars to do the same (Basya, 2015).

Discussion

Al-Biruni (973-1048) became a 10th century Islamic scholar, who had a remarkable impact towards the development of geology during those time. As many geological historians documented that there was no significant development in the field of geology at that time (Clarke, 2007), the findings of Al-Biruni are worth mentioning since it enlightens the development of geology during the Middle Ages. Although there were scholars such as Leonardo Da Vinci (1452-1519) who some consider himself for being the first renaissance geological thinker (Rajendran, 2019), Al-Biruni preceded in studying and analyzing the origin of fossils correctly. Al-Biruni's contribution in mineralogy also preceded George Bauer (1494-1556), who also contributed regarding minerals and metal. However, it is unfortunate that Al-Biruni's contribution in the development of geology during the Middle Ages has not been highlighted in the history of geological studies.

Al-Biruni's findings was not only ahead of his time, but his findings are very much aligned with the current findings and understanding of geology today. For example, in the field of paleontology, he deduced that the Himalayas was once a seabed topography by identifying sea-like creature fossils in that mountain. There is evidence and proof in today's finding

regarding what Al-Biruni deduced. For instance, there was a study done by Waagen that stated brachiopods (sea-shell fossils) (Fig.2.) as among the first Cambrian fossils reported from the Indian subcontinent and known from six different outcrops within the Himalayas (Popov et al., 2015). Probably brachiopod fossils were the same kind of fossils that Al-Biruni found during the time he was described as “stones containing shells and cowry shells” (Sparavigna, 2013).



Fig.2. Sample of a brachiopod fossil (Reed, 1910)

Al-Biruni’s thorough observation in describing the steps of extracting fossils in his book are also remarkable because for the accuracy identified in today’s paleontological studies. When Al-Biruni stated that fossils can be found in layers of dust, sand, and pebbles, it can be said that those layers of rocks are referring to sedimentary rocks. In the field of today’s paleontology, the same thing has been stated whereby fossils are formed from the remains of organism that has been covered up by sediments. Al-Biruni mentioned in his writing about the different forms of fossils that can be found well preserved, and some are hollow. In the studies of paleontology, Al-Biruni refers the term of “some are hollow” as what has been called mold or cast today (Fig.3.) (David, 2011).



Fig.3. Example of mold or cast fossils (<https://www.sites.google.com/site/fossilfinding/types-of-fossils/mold-fossils>)

Al-Biruni’s deduction about Himalaya being a sea-bed topography has also been proven in the studies of tectonic plates. Recent studies proved that the mountains of Himalaya are resulted from the convergence of the Indian and the Eurasian plates (Fig.4.) (Madden, 2012). When these two plates collide, converging crust rose forming big mountains because of their equal and high densities. The collision also scraps fragments of oceanic sediment from the Tethys Sea that separated the two plates (Vrinda & Rahman, 2017).

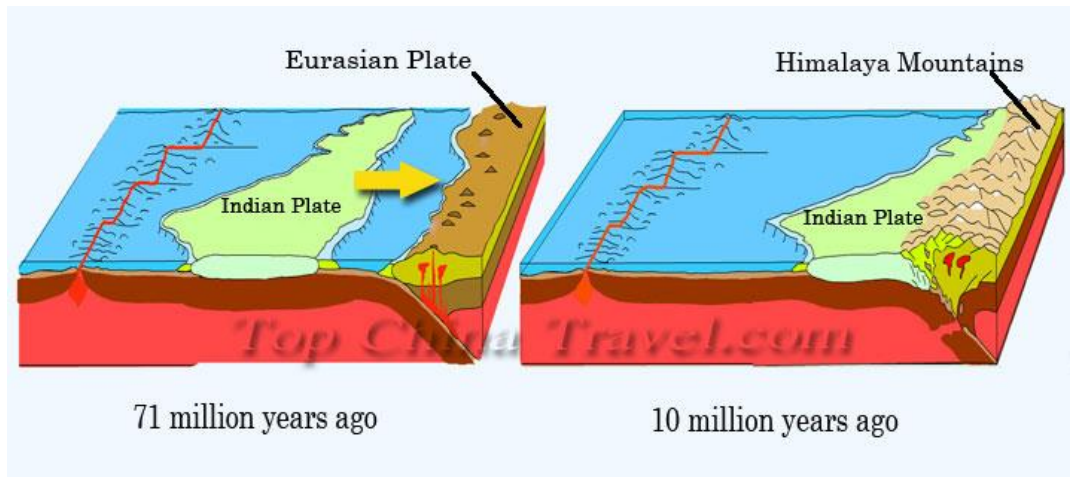
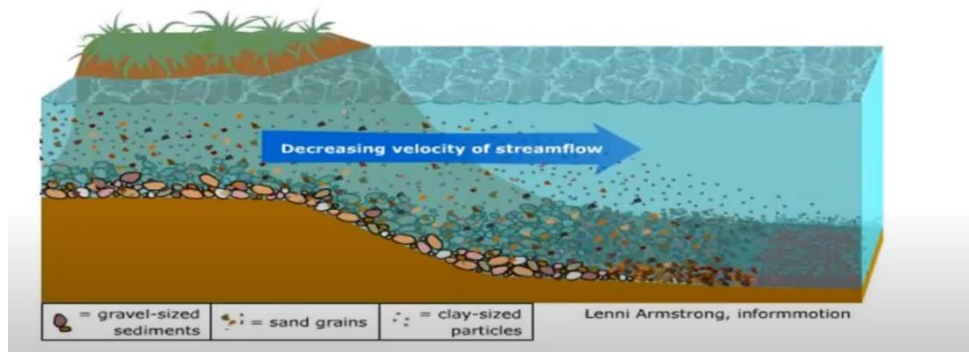


Fig.4. Formation of Himalaya by the convergence of Indian plate and Eurasian plate (<https://www.topchinatravel.com/mount-everest/how-was-mount-everest-formed.htm>)

His findings in the field of sedimentology about the alluvial deposits in the Indus Valley of Ganges Basin are also remarkable because he described perfectly on how sedimentary transportation happens as how geologist understand it today. He described it as follow:

If you consider the rounded stones found in the earth however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current; stones that are of smaller size at a greater distance from the mountains and where the streams flow more slowly; stones that appear pulverized in the shape of sand where the streams begin to stagnate near their mouths and near the sea if you consider all this you can scarcely help thinking that India was once a sea, which by degrees has been filled up by the alluvium of streams.

Our knowledge today has proven what Al-Biruni has observed. Most of present studies show the size of stones from the source zone (mountains) to the accumulation zone (sea) decreases progressively in the direction of transport (Fig.5.). The grain size of sediments must be progressively finer than its source sediment (McLaren, 1985). This is mostly due to the abrasion of current flow as the stones are being transported down the accumulation zone (Dana, 1939).



Sedimentary transportation and deposition process

(https://www.youtube.com/watch?v=jGhoggD0G7_U&ab_channel=ShailendraKumarShailendraKumar)

Al-Biruni's cone shaped apparatus to calculate the specific gravity of gems and metals was accurate enough when his results were stated as like the value of specific gravity we use today (Said, 1992). The comparison of the values by Al-Biruni and the current values of specific gravity of gems and metals is as follows (Abu Bakar, 2009):

Table 1 Comparison of specific gravity measurements of Al-Biruni and Modern measurements (Abu Bakar, 2009)

Material	Measurement with Gold	Measurement with Mercury	Modern Measurement
Gold	19.26	19.05	19.26
Mercury	13.74	13.59	13.59
Copper	8.92	8.83	8.85
Brass	8.67	8.58	8.40
Iron	7.82	7.74	7.79
Lead	11.40	11.29	11.35

Conclusion

It can be concluded that Al-Biruni made a vital contribution and impact towards the development of geology in the Middle Ages. This can be proven by his contribution in the field of paleontology, where he concluded the origin of fossils and deduced the paleo-topography of the Himalayas as once a seabed. In the field of sedimentology, Al-Biruni observed and made a remarkable inference towards the process of sedimentary transport and deposition in the Indus Valley of Gangis Basin. In the field of mineralogy, Al-Biruni found a better way of determining the quality of gems and metals which is through hardness and specific gravity that he then made accurate measurements regarding it as well. His finding was not only ahead of his time and preceded the findings of later centuries of geologist, but it is also relevant and aligned with today's understanding in the field of geology.

For these reasons, we find Al-Biruni's contribution should be better acknowledged and appreciated in the history of the geological studies as his contribution has not been clearly highlighted by geological historians.

Acknowledgements

We would like to thank the UKM Graduate Centre for the opportunity to be one of the recipients for the Zamalah Research Scheme who played a vital role so that this study can be done. Without this financial help, this study may not have been carried out and being published for people to take benefit from it.

References

- Abu Bakar, N., 2009. Al-Biruni: Ketokohan dan Sumbangan. In: Sidik, R., Che Noh, N., Tokoh-tokoh Sains & Teknologi dalam Tamadun Islam, Bangi: Jabatan Pengajian Arab & Tamadun Islam, 107-121.
- Ahmad, S.M & Baipakov, K., 2000. Geodesy, Geology, Geography and Chartography: The Silk Route accros Central Asia. In: Asimov, M. & Bosworth C. History of civilizations of central Asia. Vol IV. Delhi: Unesco Publishing
- Alavi, S.Z., 1976. Al-Biruni's Contribution to Physical Geography. Indian Journal of History of Science, 10(2), 230-234.
- Ansari, S.M.R., 1975. On the Physical Researches of Al-Biruni. Indian Journal of History of Science, Vol. 10. Issue 2, 198-217.
- Ardi, M.N., Abdullah, F., Al-Tamimi, S., 2016. Al-Biruni: A Muslim Critical Thinker. International Journal of Nusantara Islam, Vol 4(1), 1.
- Basya, A.F., 2015. Sumbangan Keilmuan Islam Pada Dunia, Jakarta: Pustaka Al-Kautsar.
- Batchelor, D.A.F., 2015. Al-Biruni: Outstanding 'Modern' Scientist of the Golden Age of Islamic Civilisation. In: Alexencer Wain, The Architects of Islamic Civilization, Selangor: Pelanduk Publications, 116-130.
- Chakraborty, A.R., 1971. Early Attempts of Documentation of Geological Literature in India – A Review. Geological Survey of India. Vol. 18 No.3, 131-137.
- Clarke, W.B., 2007. History of Geology. Primefact 563. February. http://www.resourcesandenergy.nsw.gov.au/_data/assets/pdf_file/0005/109580/history-of-geology.pdf (accessed 21.02.21).
- Dana, R.R., 1939. Effects of Transportation on Sedimentary Particles. Recent Marine Sediment, 32-47.
- David, A., 2011. Paleontology, EKF.
- Earle, S., 2014. Physical Geology - 2nd Edition, British Columbia: Bccampus Open Education. 3.
- Gohau, G., 1990. History of Geology, London: Rutgers University Press.
- Essa, A., Ali, O., 2012. Studies in Islamic Civilization: The Muslim Contribution to the Renaissanc. London: International Institute of Islamic Thought.
- Gafurov, B., 1974. Al-Biruni: A Universal Genius in Central Asia A 1000 Years Ago, Paris: UNESCO COURIER.
- <https://www.sites.google.com/site/fossilfinding/types-of-fossils/mold-fossils> (accessed 15.02.21).
- <https://www.topchinatravel.com/mount-everest/how-was-mount-everest-formed.htm> (accessed 10.03.21).
- https://www.youtube.com/watch?v=jGhgd0G7_U&ab_channel=ShailendraKumarShailendraKumar (accessed 21.03.21).
- Johnston, R.A., 2011. All Things Medievel: An Encyclopedia of the Medieval World, California: Greenwood.
- Kenedy, E.S., 1970. Abu Rayhan Al-Biruni. Dictionary of Scientific Biography. New York: Charles Scribner's Sons, 152.

- Madden, A., 2012. Overview of the Geology of the Himalayas. *Geology for Global Development*, 13.
- McLaren, P., 1985. The Effect of Sediment Transport on Grain-Size Distribution. *Journal of Sedimentary Research*, 55:457-470.
- O' Connor, J.J., Robertson, E.F., 1999. *Al-Biruni Biography*. Scotland: St Andrews University.
- Ozcep, F., Ozcep T., 2014. Notes on the history of geophysics in the Ottoman Empire. *History of Geo and Space Sciences*, 5(2) 163-174.
- Popov, L.E., Holmer, L.E., Hughes, N.C., Ghobadi Pour, M., Myrow, P.M., 2015. Himalayan Cambrian Brachiopods, *Paper in Palaeontology*, 1(4), 345-399.
- Rajendran, C.P., 2019. Shifting Paradigms: Why History Matters in Geological Sciences. *Current Science*, 117(6), 927.
- Reed, F.R.C., 1910. *Geological Magazine* n.s. dec. v, vol vii (1): p. 295 pl. xxiv figs. 9,9a-c (<http://www.3d-fossils.ac.uk/fossilType.cfm?typSampleId=20000644> (accessed 17.03.21)).
- Renima, A., Tilioune, H., Estes, R.J., 2016. The Islamic Golden Age: A Story of the Triumph of the Islamic Civilization. *The State of Social Progress of Islamic Societies*, 25-52.
- Said, H.M. 1992. *Al-Biruni*. Kuala Lumpur: Dewan Bahasa Dan Pustaka.
- Salam, A., 1984. Islam and Science. In: C.H. Lai, *Ideals and Realities: Selected Essays of Abdus Salam*, 2nd ed., World Scientific, Singapore, 179-213.
- Sparavigna, A.C., 2013. The Science of Al-Biruni. *International Journal of Sciences*, Vol. 2(12), 52-60.
- Vrinda & Rahman, J., 2017. Aftermath of the Great Collision (<https://www.thehindu.com/society/history-and-culture/aftermath-of-the-great-collision/article19882356.ece> (accessed 25.02.21)).