SCIENCE AND TECHNOLOGY IN EARLY MEDIEVAL INDIA

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As the periodization of history is controversial, there might be a difference of opinion regarding the date when the ancient period of the history of India ends and the medieval one begins but the period under consideration is actually the late ancient and early-medieval. Prithwiraj lost the second battle of Tarain in 1192 A.D. and this is considered a turning point in the history of India as it led to the conquest of northern India by the Turko-Afghans between 1192 and 1206 A.D.

India already had commercial and cultural relations with Greece, Iran, Afghanistan and Central Asia since pre-historic times. A characteristic feature of this period is that with the advent of the Muslims, seeking service and opportunity in India, it came into close contact with the Muslim intellectual world and the cross fertilization of scientific ideas started. Muslims started migrating to India more and more after 1258 A.D. due to the Mongol invasion of Iran, Iraq and Central Asia; some of them were also astronomers, mathematicians and physicians.

"With the establishment of the Ghaznavid and Mughal rule in India the Greek or rather more advanced Ptolemic astronomy in Arabic version reached India and began to be studied and taught at first exclusively among the Muslims and gradually among the selected Hindu astronomers who appreciated its merit."[1] Al-Bīrūnī (d. 1050 A.D.) claims that he had translated the *Elements* of Euclid and the *Almagest* of Ptolemy into Sanskrit but these translations are not available.[2] In any case, the Arabic version of these two books were first introduced by the Muslims in India. It is stated

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[1] S.N. Sen, D.M. Bose and B.V. Subbarayappa, *A Concise History of Science in India*, (New Delhi: Indian National Science Academy 1971), pp. 689 at p.135. (Henceforth, *CHSI*).

[2] D.G. Boilot, *L'Oeuvre d'al-Bīrūnī, Essai Bibliographique*, in the *MIDEO*, Vol. II (Cairo 1955) Nos. 175 and 176, pp. 238-239; Ahmad Saeed Khan, *A Bibliography of the Works of Abu'l-Raihān al-Bīrūnī*, (New Delhi 1982), pp. 55; M.S.Khan, "A Select Bibliogragraphy of Soviet Publications on al-Bīrūnī", in the *Janus* (Amsterdam) Oct. 1975, pp. 279-288; M.S. Khan, "A Classified Bibliography of Recent Publications on al-Bīrūnī", in the *Muslim World Book Review*, Vol. X/3, (Leicester 1990), pp. 65-77.

"towards the close of the 12th Century A.D. mathematical books in Arabic began to trickle into India. One of the most important of these treatises was an Arabic recension of Euclid's *Elements: Taḥrīr Kitāb Uṣūl al-Handasa wa'l-Ḥisāb al-Mansūb ilā Uqlīdas* (commonly called *Taḥrīr Uqlīdas*) composed by Naṣīr al-Dīn Ṭūsī (d. 672/1274) belonging to the Marāgha School of Astronomy. During Ṭūsī's life time itself Quṭb al-Dīn (d. 710/1311) prepared a Persian translation."[3]

Some Indian Muslim mathematicians and astronomers settled in India knew these Arabic translations and they translated them into Persian. These translations and several commentaries mostly in Persian on the works of Euclid, Archimedes, Theodosius, Apollonius and Ptolemy are available in manuscripts in the different libraries of India and abroad. Thus the Greco-Arab astronomy and mathematics were introduced into India and studied. Some of them were taught as text books in the educational institutions in late medieval India from the time of Akbar (d. 1605 A.D.) who made astronomy and mathematics compulsory subjects to be studied.[4]

Another characteristic worth mentioning is that the first substantial contact between the Ayurveda and Unānī (*Greco-Arab*) systems of medicine started during this period which resulted in the mutual enrichment of both in therapeutics, materia medica and pharmacology.[5] These two systems of medicine flourished because they brought relief to the suffering and the sick. The two main causes of the development of chemistry and alchemy were the practice of Ayurveda and the need of textile industry.

Among other characteristics mention may be made of the development of the *Rasacikitsā* school of medicine with emphasis on mercurial and other inorganic preparations and the development of Tantras and the knowledge of nervous system as developed by them.[6]

[3] C.A. Storey, *Persian Literature, A Bibliographical Survey*, (London 1972), Vol. II, pt 1, p. 1, Jagannatha (b. 1652 A.D.) translated the *Elements of Euclid* and the *Almagest* of Ptolemy into Sanskrit and they were entitled as *Rekhāganita* and *Samrāt-Siddhānta* respectively, see *CHSI*, p. 171.

[4] M.S. Khan, "The Teaching of Mathematics and Astronomy in the Educational Institutions of Medieval India" in the *Muslim Education Quarterly*, Vol. VI, (Cambridge 1989) Note 21 quoting Abu'l-Faḍl ʿAllāmī's *Āʾīn-i Akbarī*, ed. by H. Blockmann (Calcutta 1872), Vol. II, p.202.

[5] "Medicine as it Evolved in Ancient and Medieval India" by Priyadaranjan Ray in the *Indian Journal of the History of Science*, Vol. V, (New Delhi 1970), pp. 86-100. (Henceforth *JIHS*).

[6] S. C. Banerjee, *A Brief History of Tantra Literature*, (Calcutta 1988), pp. 660, pp. 13-17; Human Body: A Microcosm.

Mathematic and Astronomy

Both Mathematics and Astronomy were used by the Hindus and Muslims for religious purposes.[7] Mathematics specially was studied for its practical utility, as for example, for the construction of religous and secular buildings and monuments. Later, geometry was much developed in India for this purpose. It was used also for technological development.

Mathematics, astronomy and astrology were not seperate subjects as they ara to-day. More often than not, the mathematician, astronomer and astrologer were all combined in one and the same person. The outstanding mathematician-astronomers of this period were Srīdharācārya (ca. 991 A.D.); Sripati (1039-1056 A.D.), Satānanda (fl. 1099 A.D.) Bhāskarāchārya II (1150 A.D.), the major and minor mathematicians and astronomers cannot even be mentioned here and their contribution cannot be discussed due to shortage of space. "For multiplication, he uses a new term *Pratyutpanna* (reproduced) and discusses the *Kapāṭa-Sandhi* (door-junction, *Gelosia)* method which became very popular among later Hindu writers and was transmitted to the West through Arabic works. It is known from Bhāskara that Srīdhara was the discoverer of a method of solving quadratic equations in which the two sides require to be multiplied by four times the coefficient of X^{2}".[8]

There was at least one foreign scientists al-Bīrūnī (d. 1050 A.D.) who studied the Indian sciences in original Sanskrit texts and translated some of them into Arabic. He had a working knowledge of Sanskrit and his well-known book *Kitāb al-Hind*[9] gives valuable information not found elsewhere specially about astronomical methods and Indian astronomers some of whom were personally known to him. Some of the twenty-five books and treatises dealing with Indian subjects attributed to al-Bīrūnī[10] are either lost or are available in MSS only. Among those available *The Rasā'il,*[11] the *al-Qānūn al-Mas'ūdī*[12] contain useful source material for the history of

[7] See notes 13 and 14 in M.S. Khan's paper mentioned in note 4 above.

[8] S.N. Sen, "Mathematics", in the *CHSI,* p. 168.

[9] The full title is: *Kitāb fi'l-Taḥqīq mā l'il-Hind min Maqūlatin Maqbūlatin fi'l-'Aql wa Mardūla* (book giving an account of India about facts acceptable to reason or to be rejected by it).

[10] See M.S.Khan, Al-Bīrūnī and Indian Science (A Collection of Essays, Forthcoming).

[11] See the Four treatises of al-Bīrūnī published as *Rasā'il al-Bīrūnī* based on the unique (MS) Compendium of Mathematical and Astronomical Treatises in the Oriental Public Library, Patna (Hyderabad: Dairatul-Maarif 1367/1948), pp. 226 + 226 + 107 + 30.

[12] See the Edition published at Hyderabad by Dairatul-Maarif 3 Vols. 1373-1376/1954-1956, pp. LXXV + 505, 517-985 and 986-1487 + 59.

science in India in the first half of the the eleventh century. His Arabic translation of the *Karana Tilaka* of Bijayananda should be mentioned here.[13] Another work which has been edited and published is the *Fī Rashikāt al-Hind*[14] which deals with the Indian Rule of Three.

A new development in astronomy was the introduction of Arabo-Parsian-Greek *Zīj* litarature in India namely astronomical tables. Abu'l-Faḍl mentions 86 *Zijes* in his *Ā'in-i Akbarī*. There were several *Zijes* prepared in pre-Mughal India.[15]

Thare is no evidence to show that astrolabes were used in India before the advent of the Muslims. It was during the reign of Sultan Fīrōze Shāh Tughluq that an astrolabe was constructed in 1370 A.D. and named *Usṭurlāb-i Fīrōze Shāhī* which testifies to the fact that Indians possesed adequate knowledge of applied technology during the fourteenth century.[16]

People seem to be more interested in astrology than astronomy and there were more astrologers than astronomers in Delhi. Ḍiyā ad-Dīn Baranī writes about the horoscopes which they constructed of the sons and daughters born to the kings, ministers and noblemen which was an important source of their income. They earned their livelihood not as astronomers but as astrologers. He also records the names of those astronomers and astrologers both Hindus and Muslims who flourished during this period[17] and adds that pseudo-sciences such as *Ramal* geomancy and *al-Kimyā* (alchemy) also flourished during this period.[18]

[13] Also entitled *Ghurrat az-zijat* edited by N.A. Baloch (Sind: Institute of Sindhology 1973), pp. 94 (Arabic text) + pp. 74 (English Introduction and Bibliograhy) + pp. 7 (Errata). Other editions of this text have been published with English translations in the *Islamic Culture* of Hyderabad. Henceforth *IC*.

[14] The *Risala* in the *Rasā'il al-Bīrūnī* (note 11 above), pp. 1-30. A.K.Bag, "Al-Bīrūnī on Indian Arithmetic", in *IJHS*, X (1975), pp. 174-186.

[15] S.A. Khan Ghori, "Development of *Zij* Literature" in the S.N. Sen and S.K. Sukla (eds.) *History of Astronomy in India*, (New Delhi 1985), pp. 21-48.

[16] See M.P. Kharegat, *Astrolabes*, ed. by D.D. Kapadia (Bombay 1950); W. Hartner, "Asturlab", in the *Encyclopaedia of Islam* (N) Vol I, (1960), pp. 722-728; Emilie Savage-Smith, *Islamicate Celestial Globes: Their History of Construction and Use*, (Washington 1985), pp. 354; S.N.Sen, *CHSI*,pp. 126-129; Note no. 62 in "Arabic and Persian Source Materials for the History of Science in Medieval India" by M.S.Khan in the *IC* (April-July 1988), pp. 113-139 at p. 129 where profuse references are given to this instrument.

[17] See the *Tarikh-i Firoze Shahi*, ed. by Saiyid Ahmad Khan (Calcutta: Asiatic Society 1862), pp. 362-366.

[18] *Ibid*, p. 364.

Medicine, Chemistry and Alchemy

The Ayurvedic system of medicine including the Siddhā were practised extensively and in the beginning of the 13 th century the Unānī system of medicine was also introduced in India when the period of growth and standardisation of Ayurveda had almost come to an end.[19] The four standard works *Çaraḳā Saṃhitā, Susruta Saṃhitā, Aṣṭāngahardaya, Nidāna* and their commentaries were used by the general medical practitioners of India (Vaids).

"Feeling of patients' pulse as a method of diagnosis of diseases was possibly first introduced during this period as discussed in a text of Ayurvedic medicine, *Cikitsātilaka* (12th century) by Tisatācaryā."[20]

Physicians *(Ṭabīb)* expert in the Unānī (Greco-Arab) system of medicine began to migrate from the beginning of the 13th century and this was the first major contact between Ayurveda and Unānī medicine in India. Both the systems of medicine were now practised. Two different sets of hospitals were established by the Turko-Afghan rulers there the patients were treated according to these systems. There were seventy hospitals only at Delhi under Sultān Muḥammad bin Tughluq (1297-1348 A.D.) having 1200 *Vaids* and *Ṭabībs* paid by the State.[21] The mutual co-operation and direct contact of the *Vaids* and *Ṭabībs* produced substantial results and led to the mutual enrichment of knowledge. Indian pharmacology, materia medica and therapeutics were enriched by the Unānī system and camphor, sublimate of landanum and some anesthetics were introduced into the Ayurveda.[22]

Botany and Agriculture

Information about advances made in botany and agriculture are not available due to paucity of source material. The works of Amīr Khusraw

[19] R.C. Majumdar, "Medicine", in the *CHSI*, p. 262.

[20] Priyadaranjan Ray, "Medicine as it Evolved in Ancient and Medieval India", in *IJHS*, Vol. V, p. 95 quoting Julius Jolly, *Indian Medicine*, (1951), p.7.

[21] M.Z. Siddiqui, *Arabic and Persian Medical Literature*, (Calcutta 1959), p. XXIII referring to *Masalik al-Absar* by Shihab al-Din al-Umari. See also Iqtidar Husain Siddiqui and Muhammad Ahmed, *A Fourteenth Century Arah Account of India under Sultan Muhammad bin Tughlaq* (Aligarh 1971), p. 36. The part dealing with Hind and Sind of the *Masalik al-Absar* of Fadlal Lah al-Umari has been edited and puslished by Mohammad Salim ibn Shadid al-Awfi, 1st ed. (Cairo 1411/1990), pp. 277.

[22] Priyadaranjan Ray, "Medicine as it Evolved in Ancient and Mediaval India", in *IJHS*, Vol. 5 (1970), p. 96.

(651-725/1253-1325 A.D.) and and the Persian historical chronicals contain some information about these two subjects.

Medicinal herbs and plants were much cultivated. Al-Bīrūnī's *Kitāb as-Saydanah fi't-Ṭibb,* published recently with an English translation contains useful information for the pharmacographia Indica.[23] Compiled in the middle of the eleventh century, it is an encyclopedia of simple drugs containing medicinal herbs and minerals used in the Unānī system of medicine arranged in alphabetical order. There are names of hundreds of medicinal herbs and plants of India which are used in Ayurvedic materia medica. The Sanskrit name is given in each case and the location is indicated where they were found at time of al-Bīrūnī. The first traceable medical book on Unānī medicine written in India was a Persian translation of the *Kitāb as-Saydana* of al-Bīrūnī. This was translated by Abū Bakr bin ʿAlī bin 'Usmān who lived at the Court of Sulṭān Iltutmish.[24]

Technology

Without doubt, there was progress in technology but the results of technological advancement were not much applied to solve the socio-economic problems. There is no denying the fact that in so far as technology is concerned, advent of the Turko-Afghans in India resulted in some development due to mutual co-operation between the Hindus and the Muslims and the introduction of new and more advanced technique from Iran, Afghanistan and Central Asia the Muslims. It is evident that technology during this period was almost the same as in ancient India which was somewhat improved after the Ghorian conquest.

Metallurgy

Iron, copper, brass, gold, silver and other minerals were extracted from the ores found in mines in different parts of India even by a primitive technology with the help of a furnace made of clay in which wood and charcoal were used for fire. As the army was important, iron was much in use for the manufacture of arms and armour.

[23] Abu Rayhan Md. bin Ahmad al-Bīrūnī, *Kitab as-Saydana*, ed. by Mohammad Said and Rana Ihsan Ilahi with English translation (Karachi 1973). Arabic Text pp. 430; Eng trs. pp. 376. *Al-Bīrūnī's Book on Pharmacy and Materia Medica*, Introduction, Commentary and Evaluation by Sami K. Hamarneh (Karachi 1973), pp. 152.

[24] A MS of this book is said to be available in the British Museum, London, and also at the State Library, Berlin, see D.V. Subba Reddy, "The Origin and Growth of Indigenous Unani Medical Literature in Medieval India", in the *Indian Journal of the History of Medicine*, Vol. 16/1 (Hyderabad 1969), p. 20.

Production Technology

In so far as production technology is concerned, a fact to be taken into consideration is that cheap skilled labour was available in abundance in India perhaps due to the institution of the *Kārkhāna* introduced by the Muslims which made this labour easily available.

Minting of Coins

For minting of coins, mostly gold, silver, lead, bronze, brass, bullion and copper were used and Iltutmish struck the silver *Tanka* and Coper *Jital.* Abu'l-Faḍal mentions a small round gold *dīnar* issued by Sulṭān ʿAlāʾuddīn Khaljī whose refinement was considered to be 12 degrees [25] but it was actually 10 1/2 degrees. The technology of Indian coinage in ancient and medieval periods has been thoroughly discussed in a paper published recently.[26] The details are known from a Sanskrit work written during the reign of ʿAlāʾuddīn Khaljī.

Textile Technology/Spinning Wheel

The premier industry in India was cotton textile and dyeing, printing and painting of chothes was done since ancient times. In connection with the innovation in textile technology, the general use of the spinning wheel is to be mentioned. It would not be possible to ascribe its origin to ancient India due to lack of positive evidence.[27] Moreover, the word used for it is *Charkha* which is a Persian word. In the absence of any other evidence, the literary ones from Indo-Persian works can be put forward to show that the spining wheal was in use at the end of the 12th century in which belt-drive technique was used.[28] Another equipment which was much used in this period was the bow-string *(Tānt* and *Kamān)* for cleaning the cotton and separating the seeds from it or ginning.[29] This primitive technique is used in India to-day.

[25] Abul-Fadl Allami, *Āʾīn-i Akbarī,* ed. by H. Blockmann, Vol. 1 (Calcutta 1872) *Ain* No.5, p.14. Eng. Trans. by H. Blockmann, Vol. I (Calcutta 1873), p.18.

[26] B.N. Mukherjee, "Technology of Indian Coinage, Ancient and Medieval Period" in the Aniruddha Roy and S.K. Bagchi, *Technology in Ancient and Medieval India,* (Delhi 1986), pp. 47-70. (Henceforth *TAMJ).*

[27] Lynn White, "Tibet, India and Malaya as Sources of Western Mediecal Technology," in the *American Historical Review,* Vol. LXV/3 April (1960), p. 517.

[28] See Irfān Ḥabīb, *Presidential Address, Proceedings of the Indian History Congress,* 31st Session, held at Varanasi 1969, (Patna 1970), pp. 142-143. (Henceforth Presidential Address).

[29] 'Irfān Ḥabīb, *Presidential Address,* p. 144. Its vibrations loosened and separeted (scutch) the cotton fibres; Ishrat Alam, "Textile Tools as Depicted in Ajanta and Mughal Paintings", in Aniruddha Roy and S.K. Bagchi, *TAMI,* pp. 129-141.

Writing Material

It is al-Bīrūnī who gives the evidence around 1030 A.D. that the material used for writing in India were mainly black tablets palm-leaves, bark of the Tuz tree called Bhurja and silk.[30] The manufacture of white paper started in India in the 13th century. Amīr Khosraw mentions paper *(Kāghaz)* several times in his epistolary work entitled *I'jāz-i Khusrawī*[31] and in his above mentioned *Qiran as-Sa'dayn.* He states that paper was made with cotton, linen-cloth, silk *(Qash, Harīr)* and reed *(Kilk).* They were soaked in water, then pounded and turned into pulp with which the sheets of paper were made and dried. After that, they were cut out according to size with a sharp scissor and adds that this light paper was quite costly.[32] As regards preparation of ink, the earliest recipes for hair dye making in India is found in the *Navanitaka* (Ca.2nd Cent. A.D.). From this Nityanath Siddha (1200 A.D.) derived his recipes for ink making as recorded in his *Rasaratnākara*[33] (1200 A.D.). The materials used for this were herbal substances or metalic ingredients. The ingredients used were lamp-black, charcoal, gum, burnt husk of almond, gold and silver powder and others.[34]

Irrigation Technology

Generally, water was stored in tanks and wells, canals and channels were dug for irrigation in ancient India. Tank was used extensively in the South for irrigation and very large tanks were dug at this period. Among others, there was the Porumamilla tank of great dimension which bears an inscription dated 1291 A.D.[35] There is a difference of opinion about the device for water raising used in Ancient India called *Araghatta* or *Ghati-Yāntra* which are Sanskrit words. On the basis of this, several scholars have argued that it was the same as the Persian wheel or *sāqiyah* and it was not

[30] See the *Kitāb al-Hind,* (Hyderabad 1958), p. 146; Eng. trans. by E.C. Sachau, (New Delhi reprint, 1964), Vol. I, 182. See also text p.133; trans. p. I, 171.

[31] Lithographed, Nawl Kishore Press, Lucknow 1865, p. 45.

[32] Edition cited in note 31 above pp. 228-229. See also p. 177; Mamata Chowdhury, "The Technique of Preparing Writing Materials in Early India with Special Reference to al-Bīrūnī's Observations", in the *IC,* Vol. XLVIII, No. 1, (January, 1974), pp. 33-38.

[33] P.K. Gode, "Recipes for Hair Dye in the *Navanītaka* and their close Affinity with the recipes for Ink Manufacture after A.D. 1000", in the *Studies in Indian Cultural History,* Vol. I, (Hoshiyarpur 1961), pp. 101-110. See also Mamata Chowdhury, *op. cit.,* p. 38.

[34] Priyadaranjan Ray, *History of Chemistry in Ancient and Medieval India,* pp. 73 ff. Henceforth *HCAMI*; B. R. Pandey, *op. cit.,* pp. 82-85; D.C. Sirkar, *op. cit.,* pp. 80-81.

[35] S.P. Roy Chowdhury "Agriculture", in the *CHSI,* p. 367.

introduced by the Turko-Afgans in India but these two words are nowhere clearly mentioned or explained in any early source.[36] It was actually the simple *noria* a wheel carrying pots and buckets fixed on its rims which did not involve the technique of gearing. That it was *noria* and not exactly the Persian wheel has been confirmed by the extensive researches of Thorkild Schioler.[37] The generally accepted view at present is that the Persian wheel was introduced by the Turko-Afghans in India in the 13th century. It was useful for raising the water from wells with the help of a chain of buckets in which the circular motion was obtained by animal power mainly bullocks using the technique of pin-drum gearing.

Ship Building

The technique employed for building of ships used in the Indian Ocean need not be discussed here. It would be sufficient to state that planks of the hull were sewn together by coir and generally not nailed.[38] An Arab geographer Ibn Rustah (fl. ca. 290-300/903-913) records that planks of ships used by the Arabs in the Indian Ocean were sewn with cords of coconut and palm fibre and iron nails were not used till the beginning of the eighth century.[39] The statement of the Arab geographer al-Masʿūdī is quite clear on this point. He states "Now this kind of structure (stitching) is not used except in the Indian Ocean; for the ships the Mediterranean and those of the Arabs all have nails, whereas in ships of the Indian Ocean iron nails do not last because the sea-water corrodes the iron and the nails grow soft and weak in the sea and therefore the people on its shores have taken to threading cords of fibre instead and these are coated with grease and tar.[40] "Ibn Baṭṭūtah who arrived in India in September, 1333 have a detailed account of the technique used in the manufacture of Indian ships."[41]

[36] A. L. Basham, *The Wonder that was India,* 3rd Rev. edition, (London 1967), p. 194.

[37] See his *Roman and Islamic Water-Lifting Wheels,* (Odense 1973), and Joseph Needham, *Science and Civilization in China,* Vol. IV/Part II, (Cambridge 1965), pp. 330-334, 352-356, "Hydraulic Engineering: Water Raising Machinery."

[38] George Faḍlō Ḥourānī, *Arab Seafaring in the Indian Ocean in Ancient and Early Medieval Times,* (Princeton 1951), pp. 91-94; Syed Sulaymān Nadvī, *The Arab Navigation,* translated by Syed Sabahuddīn 'Abdu'r-Raḥmān, (Lahore 1966), lst ed., p.118.

[39] Ibn Rustah, *al-Aʿlāq an-Nafīsah,* (Leiden 1891), pp. 229 at p. 196.

[40] George Fadlō Hourānī, *op. cit.,* p. 96 quoting the *Murūj adh-Dhahab* of al-Masʿūdī, (Paris ed.) Vol. I, p. 365.

[41] See *Rehla* or *Travels in Asia and Africa* (1325-54) trans. and selected by H.A.R. Gibb (London: Routledge and Kegan Paul 1957), p. 243.

Architecture

Magnificient stupas, temples and other sacred monuments both in the north and the south constructed during this period bear testimony to the highly developed building technology in India.

Without doubt, Indian builders were employed by the Muslim rulers for the construction of monuments but several expert masons and craftsmen were also brought from Persia and Afganistan introducing the Arabo-Persian architectural and decorative traditions. They had to build within the Islamic conceptual framework which strictly prohibited the represantation of human figures in any building. They took recourse to the use of the beautiful lettering of the Qurānic verses and employment of leaves, flowers and buds drawn from the flora and from geometrical designs (*arabesque*). This brought about great changes in the technology and style of architecture in India. The imported style consisted of domes roofing, half-domed portals, minarets (*minār*), pendentive and squinch arches introduced at the order of the Sulṭāns and nobles. In so far as building material is concerned stones and bricks were necessarily used and lime-mortar was employed perhaps for the first time in India by the Muslims.[42] The Indian masons had to build false arches on trabeate principles.[43]

Glass Technology

The more archaeological excavations ara carried out in different parts of the country, the more it is established that glass-making was widespread in ancient India. So many articles made of glass have been discovered, especially at Kopia in U.P., Taxila, Satavahana sites and others that it cannot be argued that all of them were foreign goods imported from outside. Most of them are beads, bangles, bowls, slags, small vessels, tiles, glass-flasks and others. But very little information is found concerning the technique of glass-making for example about raw materials, furnace and tools used. Howover, the raw materials used were soda, lime, alumina, excreta of mica, sand mixed with saline earth.[44] Primitive open circular or square furnace was used and the temperature of heat was about 1000° centrigrade.

[42] 'Irfān Ḥabīb, *Symposium Lecture*, p. 16.

[43] 'Irfān Ḥabīb, *ibid.*, p. 17; James Fergusson, *History of Eastern and Indian Architecture*, (London 1910), Vol. II.

[44] Mamata Chowdhury, "The Technique of Glass Making in India", Paper presented at National Seminar on Technology and Science in India during 1400-1800 A.D. held on 20-81 April 1978, Indian National Science Academy, New Delhi; Priyadaranjan Ray, *HCAMI*, pp. 73 ff. See also M. G. Dikshit, *History of Indian Glass*, (Bombay 1969), pp. XIII + 212 + 48 plates.

Military Technology

Two important equipments showing change or innovation or development in military technology of this period have to be mentioned first i.e. the flat iron stirrup and nailed horse shoe. It is generally asserted that stirrup because was in use in ancient India, but avalilable evidence shows that the flat iron stirrup was introduced by Turkish conquerors in early 13th century.[45] They had to use the iron stirrup because they laid emphasis on the cavalry and their tactic of battle was mounted shock combat. The nailed horse shoes were not used in India before the Turko-Afghan conquest although they were in use in Byzantium at the end of the 9th century A.D.[46] Two statements in the *Ādāb al-Ḥarb* of Fakhr Mudabbir suggest that the horse shoes were used in the beginning of the 13th century. The above work of Fakhr Mudabbir which was written around 1225 A.D. gives first-hand information about military technology specially about the manufacture of all kinds of arms and armour in which mostly iron and steel were used. In this work, there is one full chapter entitled "On the virtues and specialities of each weapon and the advantege of making use of it namely regarding the situation in which each one is useful. It runs into 34 closely printed pages of the present text."[47]

In modern terminology, the technique of manufacture of a sword will mean that the two ingots were coverad with soft earth in order to prevent loss of carbon; both the ingots were made into ona piece or forge-welded by hammering when iron/steel was made soft under a temperature of 1000°-1200° centrigrade. The process of hardening of steel by quenching red hot metal into water or oil is employed even to-day. The first hammering was for preparing a blank while the second hammering was to give it the shape of a sword. The blunt sword was sharpened on an abrasive wheel and polished later on with oxymel.[48]

Artillery and Gunpowder

The question arises whether artillery, gun and gun powder were used befere Babar's time (A.D. 1526) or not. This is a controversial issue. Some historians state that mechanical artillery was in use in India as early as the first quarter of the 13th century, others are of the view that it was used

[45] See 'Irfān Ḥabīb, Presidential Address, p. 158 quoting Fakhr Mudabbir.

[46] See 'Irfān Ḥabīb, *Symposium Lecture,* pp. 26-27.

[47] See *Kitāb Ādāb al-Ḥarb wash-Shajā'ah,* Chapter XI, pp. 249-273. Henceforth *KAHWS.*

[48] Konasudaram near Hyderabad was well known for the manufacture of Wootz a kind of steel manufactured by mixing iron with carbonaceous matter.

in 1365/66 A.D. The *manjanīq* or *catapult* was used by the Muslims for hurling huge masses of stone towards the enemy or a fort. This worked by "three different principles of torsion, counterpoise and tension." Naphta or Greek fire was used by the Turko-Afghan invaders but this also may mean gun-powder. Two historians express the view that artillery was used in India much before Babar in the reign of Sulṭān Iltutmish of Delhi.[49] On the other hand, R.C. Majumder states that artillary was used in India in the 14th century.[50]

Concluding Remarks

One of the difficulties in writing this history is that the source matarials especially the manuscripts in Sanskrit, Arabic and Persian have not been edited and published. Some of them are uncatalogued so that they are unknown even to those who do research work on the history of science in India. Therefore, it is evident that a thorough assessment of India's contribution to scientific and technological develoment is not possible now. Thus it is not claimed that the history of science and technology in late ancient and early medieval India presented here is either thorough or complete.

[49] M.A. Makhdoomee, "Gunpowder Artillery in the Reign of Sultan Iltutmish of Delhi", in the *Journal of Indian History*, Vol. XI, pts I and III (1936), pp. 185-188; "Mechanical Artillery in Medieval India" in *loc. cit.*, pp. 189-195; Abū Zafar Nadvī, "The Use of the Cannon in Medieval India", in *IC*, Vol. XII, (October 1938), pp. 405-418. For *Kushk Anjīr* see *KAHWS* p. 424.

[50] See the Delhi Sultanate, *History and Culture of the Indian People*, (Bharatiyah Vidya Bhaban), Vol. VI, p. 460.