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## Material Culture, Technology and the Historiography of the Middle East

Jean-Luc Krawczyk

The study of material culture and technology within a historical context is sadly underdeveloped in most fields of history, yet it holds much promise as a methodological adjunct to many modes of historiographical analysis. This is especially true in the case of Middle Eastern history where it could- and in the future, should- illuminate and fill out some of the lacunae now present in many standard historiographical interpretations. In the past, much of Middle Eastern historiography adhered to a now outdated tradition that tended to view everything that occurred in the Middle East as a direct cultural product of Islam. This so-called "Orientalist" tradition, with its stress on philology, politics and religion has been supplanted by a subsequent generation of historians who pay more attention to socioeconomic factors in their analyses. Yet, even here, their discussions may overstress trade, or center almost exclusively on dependent relations with the West; this is especially true in regards to the history of the modern Middle East. For a Marxist or a materialist historian this may take the form of an abiding interest in the nature and form of class relations to the detriment of the means of production. Since both the means and relations of production are inexorably intertwined, it makes little sense to stress trade exploitation, dependency and class structure without examining the actual productive capabilities of a society and including them into one's final analysis.<sup>1</sup>

Material culture encompasses both technology and the objects or processes it produces for human use and consumption. A geographical

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and/or ecological component must also be included in and appended to the concept of technology since both merge in forming the material basis of all societies and affecting, to different degrees, all individuals included therein. A wholistic historical approach which stresses material culture and ecology is being practiced by French historians of the *Annales* school such as Fernand Braudel and Emmanuel LeRoy Ladurie, and by their American counterparts, William McNeill and Lynn White. For Middle Eastern historians, however, this approach is just now beginning to receive the attention it deserves.

A good example of how this methodology may be applied in the future is afforded by a cursory examination of the rates of growth of the Middle East's economy vis-a-vis Europe during the former's classical period (i.e., the seventh to the sixteenth centuries). Comparative questions of rise and decline are by no means easy as they can fall prey to the polemical biases and confessional interests of different scholars- usually in the form of excessive apologetics or downright chauvinism. That Western Europe experienced a period of tremendous material expansion while the Middle East's economy seemed to stagnate, or even regress, in the later Middle Ages is a phenomenon that seems to be irrefutable. The question then arises as to why this occurred. Religio-cultural factors aside, we may be able to perceive some ecological, geographic and material factors that combined with- or may have even produced-specific socioeconomic and political circumstances that engendered this long run disparity in the Middle East.

A stress on long term processes is unavoidable when dealing with ecological or physiobiotic factors; change is gradual, not abrupt and easily delineated as many historians perceive it. For the historiography of the Middle East addressing such problems will help immensely in the understanding of the field, likewise, it will also serve as a catalyst for the development of new areas of inquiry.

### **Agriculture and Pastoral Nomadism**

The question of long term agricultural production and the improvement of methods and techniques is paramount for an historian of material culture. Production of a stable agricultural surplus is at the root of the establishment and maintenance of all pre-modern civilizations. Greater surplus accumulation produced higher levels of political differentiation and cultural sophistication, spurred on by a need for greater internal political organization and an increasingly complex division of labor. The earliest agrarian civilizations arose in the Middle East as functional adaptations to local physical conditions. Centralized political entities were easier to establish in the relatively flat and semi-arid riverine systems of

the Middle East than in the temperate, well watered and heavily forested environment of Northern Europe. The former placed a premium on irrigation agriculture which in turn necessitated greater local cooperation, organization, and upkeep. The latter had no such imperative, and was thus slower to evolve from hunting, gathering, and simple bartering to the point where it needed to adopt the trappings of a differentiated civilization.

Andrew Watson of the University of Toronto has just written a new (and what we believe will be viewed in the future as a seminal) book entitled *Agricultural Innovation in the Early Islamic World* (Cambridge, 1984).<sup>2</sup> In it Watson traces the development and long term effects of what he calls the "green revolution" that followed the Muslim conquests during the course of the middle and late seventh century A.D., and the early eighth. The relative speed and incredible breadth of these conquests brought the Arabs into close contact with a number of older and more sophisticated civilizations. Along with the possibility of new commercial contacts, the Arabs took notice of and adopted certain customs, techniques, political institutions and knowledge from these more advanced civilizations and synthesized them into their own brilliant culture (e.g., from the Byzantines, Persians, Indians and Chinese). They also brought back with them and adopted a number of new plants and fruits. These new crops began to appear in the easternmost reaches of the Islamic world by the beginning of the eighth century, and had spread through the length and breadth of the *Dar al-Islam* by the eleventh. They often radically modified and improved the economic output of many different regions. The subsequent results were manifold; not only was agricultural production and overall income affected, but so were population levels, urban growth, labor distribution, linked industries, cooking, diet, clothing, and commerce.<sup>3</sup> The agricultural revolution was also bound up with a demographic expansion that spread through most of the Islamic world from the early eighth century and lasted until the end of the tenth. Demographic growth resulted at times from agricultural expansion, while at others it must have been its efficient cause.<sup>4</sup>

The consequences of such demographic growth were extensive. Previously empty spaces were filled up, settlements became denser. This in turn further eased communication and, theoretically, the speed by which agricultural innovations were diffused and applied.<sup>5</sup> The countryside seems to have been able to adequately feed not only itself, but also the large and growing urban centers. Much of the rise in productivity was due to the adaptation of these new imported tropical and sub-tropical crops to a summer season in the Middle East. Previously, as was the tradition of the agriculture of antiquity, summer was a dead season in these arid and semi-arid lands. High heat and a lack of adequate

precipitation necessarily mitigated any attempts at planting, land and labor lay idle instead.

With the introduction of new imported crops such as rice, sugar, cotton, indigo, watermelons, bananas, eggplants and the like, Middle Eastern farmers could now mix and match specific crops to varying local soil and hydraulic conditions. Agriculture became a year round proposition with the introduction of a quadriannual crop rotation. Agriculture, however, could not hope to meet a consistently high level of productivity without the support of a sophisticated irrigation system that was in turn aided by extensive and varigated use of different manures and hoeing, digging and harrowing techniques. What emerged was a complex, productive, and efficient agriculture that stressed specialized adaptation, maximized output, and was labor and capital intensive. It was, however, a very fragile agriculture.

Irrigation agriculture as practised in the Middle East had serious long-term drawbacks. It took a great deal of maintenance and capital investment to keep the system in good operating condition. This was predicated on both a stable political climate and a steady fiscal base to maintain a high degree of operational efficiency. In times of relative stability and fiscal strength on the part of the state and local authorities, this could be maintained adequately. But if either, or both, prerequisite conditions were not met, agriculture suffered heavily. With the increasing fragmentation of the Abbasid Empire and its concomitant loss of centralized political authority, from the beginning of the early ninth century to its actual destruction in the mid-tenth, agricultural conditions in the core areas of the Middle East steadily worsened. Political and military instability, common to political systems that increasingly relied on imported Turkish military slaves (i.e., the Praetorian guard syndrome), and a worsening tax burden on the peasantry only exacerbated the situation. Watson's view of a great interest in agriculture by the Arabs is also shared by the eminent French historian, Claude Cahen. Like Watson, Cahen states that Muslim agriculture flourished in the early Middle Ages but began to noticeably decline in later periods along with the breakdown of strong centralized empire systems and the rise of local foci of authority (i.e., Balkanization).<sup>6</sup>

Perhaps more serious in the long run were the twin problems of salinization and deforestation. Continuous irrigation builds up a pressure gradient that gradually draws salts- and in modern times, chemical pollutants up to the soil surface from the water table below. This effectively ruins the soil for further cultivation as there is little or no way of reversing the process. Over time sizeable tracts of irrigated land in Iraq, Egypt and other parts of the Middle East were permanently lost to agriculture due to such overuse. For an excellent study of irrigation and its

sometimes deleterious effects the reader should consult Robert McAdams, *Land Behind Baghdad: A History of Settlement on the Diyala Plains* (Chicago, 1965). The phenomenon of salinization is well known throughout Middle Eastern history, and it appears at different times in other parts of the world as well.

Deforestation resulted from the Middle East's relative scarcity of wood compared to Europe and other areas in general. Consumption for fuel and building material stripped much of the forest land relatively early. The famous cedars of Lebanon were already being harvested in large numbers in antiquity. Such consumption of precious wood resources was, on the whole, detrimental not only to industrial development but to agriculture as well. Trees and cover vegetation play an important role in anchoring soil and preventing erosion. Over the long run, much valuable topsoil was lost as its protective vegetative cover was stripped away for other uses. This sort of man-made "dust bowl" was to have negative long term results for the Middle East. For a thorough examination the reader should consult J.V. Thirgood's, *Man and the Mediterranean Forest: A History of Resource Depletion* (London and New York, 1981).

No account of Middle Eastern agriculture can be complete without dealing with the question of pastoral nomadism and its relation to the agricultural sector. The popular image of the Middle East is that of a land filled with camel riding nomads. This is very misleading since pastoral nomads have never made up more than a small percentage of the population. Nevertheless, they have historically been very important for the role they have played.

The semi-arid and generally marginal lands of the Middle East can be most efficiently utilized by having a combination of pastoral nomadism and agriculture. Optimally, the two forms of economic production should complement each other in a symbiotic relationship that maximizes the use of the environment. In reality, the organizational imperatives are such that a competitive and antagonistic relationship often results. Mutualism may occur, but this is only dictated by a delicate balance of power between a centralized regime interested in protecting its primary source of revenue and tribal nomads who covet agricultural land as pasture for their flocks. In times of strong central power pastoral nomads fit into the interstices between agricultural land and the desert or steppe. When the situation is reversed, as it often was, the nomads sometimes ravage agricultural land and villages in a drive to maximize their short-term profits. Their always high potential for military mobilization and rapid movement gave them a far greater strategic importance than that dictated purely by their numbers. They could, therefore, be just as destructive to agriculture as any natural disaster.

Organized large scale invasions of the Middle East by pastoral nomads, such as those of the Seljuq Turks in the eleventh century, caused a great disruption of the agricultural sector and had momentous demographic repercussions. As more agricultural land was converted to pasturage for nomadic flocks, food production was lowered and urban centers began to attenuate. The same process was to be repeated, perhaps even more violently, in the course of the thirteenth century with the advent of the Mongol invasions. It is for this reason that historians mark the eleventh century and the coming of the Seljuqs as a watershed in the history of the Middle East, and as a benchmark for the diminution of agriculture. A new equilibrium between pastoral nomadism and agriculture was reached, but in many ways it can be viewed as a traumatic intensification of a process of competitive interaction occurring since antiquity. It can also be argued that the long term trend towards increasing aridity spurred on more pastoral nomadism at the cost of agriculture, and that large scale invasions only exacerbated this process. Needless to say, this is a very complex question which can also be argued from the other direction and will, no doubt, keep interested historians and anthropologists busy for some time to come.

Pastoral nomads are rarely, if ever, economically self-sufficient. Stock-raising alone is usually not enough to guarantee their successful reproductive capabilities. This must inevitably be supplemented by adjunct economic activities such as part-time farming, trading, hunting, transport and in a number of cases, day labor. The close interaction between "the desert and the sown" is best illustrated by analyzing the productive capabilities of a pastoral nomadic group *in toto*. The measure of relative productive wealth can be best understood when it is established against a background of all possible sources of pastoral nomadic wealth, including interchange with sedentarized society. These sources of wealth, or poverty as the case may be, are dictated by physio-biotic factors (i.e., ecology), commercial activities, and political relations with the centralized state. Sedentary agriculture, commerce and manufacturing, which are merely controlled and taxed by pastoral nomads when they manage to seize control of territory, fit part and parcel within this nexus. In effect, a conjunction of the pastoral nomadic economy with the sedentary agricultural and urban commercial ones is evident.

Works on pastoral nomads by anthropologists are legion and need not be mentioned here, but it must be noted that historians are now beginning to gain a fuller understanding of this phenomenon and are increasingly appreciating the methodology of anthropologists. Synchronic and diachronic viewpoints are converging and producing works of great synthetic value. Historians such as Gene Garthwaite, Fred Donner, James Reid and John Masson Smith, among others, are writing "tribal history."

a relatively new field of endeavor. Of more relevance for this essay, however, is the new work by the French anthropologist Jean-Pierre Digard entitled *Techniques des nomades Baxtyâry d'Iran* (New York: Cambridge and London, 1982). This is the inaugural volume of his study of these pastoral nomads, and it should be a landmark for anthropologists and historians alike as it attempts a synthetic and wholistic integration of all aspects of a particular nomadic people's lifestyle, habitat, material culture and historical development. His is a welcome addition to the field in that it incorporates both standard ethnography with the material culture approach of the French Annales school.

### Fuel, Power and Industry

If agriculture's development and its relationship to pastoral nomadism poses us with compelling questions and problems, then so does Middle Eastern mechanical engineering and industry. To a modern observer the word industry usually conjures up images of large factories, steel mills and assembly lines. But these are relatively modern developments that have their genesis in the capitalist development of Europe. "Industry" in a medieval context usually signified much smaller operations, often at the level of handicrafts and small workshops. For the Middle East this included such pursuits as mining, metallurgy, milling, sugar refining, papermaking, textiles, shipbuilding and a horde of more specialized crafts. An excellent study of the material life of medieval Egyptians can be found in S.D. Goitein's magisterial work, *A Mediterranean Society* (Berkeley and Los Angeles, 1967), vol. I, *Economic Foundations*. Likewise for Iran, the reader should consult H. Wulff, *The Traditional Crafts of Persia* (Cambridge, 1966).

A crucial criterion for the definition of industrial versus artisanal forms of production is not only the question of size and volume, but whether or not sources of power outside of human and animal labor were applied to manufacturing processes. Sources tell us that waterpower, apart from grain milling and irrigation, was used in mining, sugar refining, and in all likelihood, papermaking.<sup>7</sup> The critical development for large scale industrial processes, however, was the creation of effective power trains by which the motive power of water, wind or fuel was directly transferred to a particular task, thus generating a level of force and productive output that was not possible before. The application and use of varigated and large scale power trains was a hallmark of an expanding European economy but it appears to have been comparatively lacking in the Middle East.

The scarcity of textual and archeological evidence for Middle Eastern mechanical engineering, as compared to what is available for Europe, is a



problem for historians. The few extant sources that are found tell us that medieval Muslim mechanical engineering was complex and well developed, at least on a theoretical design level. For an excellent overview the reader should consult the work of Donald Hill and Ahmad al-Hassan.<sup>8</sup> Their research on the work of the Muslim engineers al-Jazarī (ca. 1200 A.D.), and al-Jayyānī (d. 1079 A.D.), paints a fascinating yet incomplete picture. The machine designs they describe are noteworthy for their sheer size, power and obvious industrial applications. These machines exhibit the use of several forms of gearing, including parallel meshing, right angle, worm and pinion, segmental, and even epicyclic gearing. These findings were rather startling for both men, as they illustrate systems for transmitting torque that are much more complex than any other power-driven gears known to have existed so early.<sup>9</sup> It becomes apparent, therefore, that medieval Muslims did have the prerequisite knowledge to design advanced power trains for their machines, but the question of the extent of the actual implementation and use of these machines, if any, is still unanswered and must be found elsewhere.

Related to the above is the role of available sources of fuel and power and their role in furthering industrial development. Europe had a distinctive advantage over the Middle East in terms of available power, including wood, coal, and running water that could be harnessed for economic processes. All three were indispensable for the development of the material infrastructure of a machine industry. Wood provided fuel, building material and a source of badly needed ground cover for agriculture. Its relative paucity was to be of serious consequence for the Middle East, for as Fernand Braudel has stated: "The fact that wood was used everywhere carried enormous significance in the past. One of the reasons for Europe's power lay in its being so plentifully endowed with forests. In the face of it Islam was in the long run undermined by the poverty of its wood resources and their gradual exhaustion."<sup>10</sup>

Such an environmental constraint limited the growth of industries that consumed large amounts of fuel like the manufacture of pottery, glass, sugar, and various metallurgical processes. The lack of adequate fuel for the maintenance of consistently high heat in metallurgy hampered in turn, as Thomas Glick believes, the overall use of iron in comparison to Europe.<sup>11</sup> Indeed, one of the most important advances in metal working was the European application, in the Middle Ages, of water power to produce an air blast that permitted the production of cast iron.<sup>12</sup> Presumably, this combination of water power, with plentiful available fuel, provided a high and constant enough heat to make both cast iron and steel on a decidedly large scale. A modern example of this dilemma of adequate fuel is found today in North Africa, where fruit pits are used to produce ample heat in small-scale backyard furnaces.

The lack of adequate fuel supplies necessarily circumscribed Middle Eastern metallurgy on a quantitative but not qualitative level. The technical level of this industry was otherwise quite high and well developed as the research of scholars such as J. Piatkowski and Ahmad al-Hassan attests.<sup>13</sup> But this may have meant that iron and steel production was more often than not monopolized by the state for its strategic interests at the expense of its widespread use by the rest of society. Problems directly linked to resource attrition, however, do appear. By the sixteenth century, Morocco's iron and steel industry began to stagnate due to a shortage of adequate fuel for its furnaces. Lower temperatures resulted in poor refining rates for both metals to the point that cheaper and more readily available European iron and steel eventually replaced local production. The destruction of this local industry by a more efficient and competitive product damaged the economy and retarded the further development of Moroccan metallurgy until well into the twentieth century.<sup>14</sup>

Similarly, we can also point to the work of Paul Berthier on the Moroccan sugar industry and witness a homologous phenomenon.<sup>15</sup> What had been an old and thriving industry literally destroyed itself by degrading the natural resources that underlay its foundation. The complex of sugarcane plantations, the irrigation system that served them, and the refineries that produced the final product suffered from long term overconsumption of soil, water and combustible wood. Excessive soil degradation by plantations- sugarcane is not unlike cotton in this respect- and deforestation damaged the industry beyond repair. The drive to scour the countryside for all available natural resources contributed to the ruination of both industrial and agricultural concerns.

In the early nineteenth century, Muhammad Ali Bey (A.D. 1805-1848), the father of modern Egypt, attempted to modernize his agrarian society against great obstacles. He ultimately failed, fighting European economic and geopolitical interests along with internal problems, one of which was the chronic shortage of fuel to power the imported steam engines that were to run his new and modern industrial sector. It was, of course, a concatenation of different factors that led to the failure of Muhammad Ali's modernizing experiment. The shortage of available fuel was only one among many problems he had to face, but it was a crucial one nevertheless, and it serves as a constant reminder of the long range historical implications of a changing physio-biotic environment of which historians should be well aware. There is a constant interplay of material and socioeconomic factors that go into the economy and society of a particular culture.

## Conclusion

The above has presented a very general and thematic introduction to some of the more salient questions and problems for historians of the Middle East who are interested in integrating technology and material history into their work. One may ask the question, why is this really necessary for an already developed field? The answer is that Middle East historians operate at a distinct disadvantage vis-a-vis other fields of history such as American or European. The Middle East suffers from a distinct lack of archival material to work with, especially for the earlier periods, and historians must instead rely on written histories and literature, in order to reconstruct the past. As a result, adjunct research skills must be developed in order to supplement and fill in the cracks left where literary sources leave off, so as to bring our understanding of the Middle East nearer to the level of our knowledge of the West.<sup>16</sup>

Middle Eastern historians are already cultivating ancillary skills in such fields as archeology, anthropology, art history, geography, and the history of technology in order to supplement the historical tools available to them and to maximize the manner in which various sources such as pot sherds, architecture, and geographical surveys can be made to "speak." This does not mean that these historians should embark upon the exhaustive study of new fields, for even a minimum working knowledge of one of them will help immensely. Historians are often put off and intimidated by seemingly overly technical works that are in reality not that difficult to understand. A number of historians have published excellent works on technology even though they themselves lacked great technical expertise.<sup>17</sup>

Part of the problem is that technological work appears not only forbiddingly difficult, but it is seen as overly descriptive scholarship that merely catalogues disembodied things without placing them within a frame of reference that describes their dynamic function and historical importance. It is true that a number of technological historians have fallen prey to an all consuming monomania and fetishization of the objects they study as primary causal factors in history. The correct approach is to imbed technology and material culture within a greater theoretical framework that integrates all historical factors. No one should be pejoratively dismissed as a technological or geographical determinist.

Agriculture, salinization, deforestation, dessication, pastoral nomadism and fuel and industry, constitute important, but often overlooked, backdrops to the more pronounced leitmotifs of politics, religion and commerce in Middle Eastern historiography. Each topic should be studied on its own, but they should all be tied to social change and historical movement. Agriculture declined after the eleventh century due to

salinization, deforestation, and political insecurity, but how was it affected by overcrowding on the land, a decline in free small ownership, the growth of increasingly inflexible class-divided landholding systems, the rise of military quasi-feudalism, and invasion, occupation and rule by nomadic conquerors? Similarly, the rise of militarily dominated regimes in the later Middle Ages was marked by ever increasing state control of the economy to the detriment of free competition and the gradual weakening of the Muslim bourgeoisie. An important article by E. Ashtor shows how the slow strangulation of competition negated the need for innovation in industry, and, presumably, investment in new technology.<sup>18</sup> These developments combined with resource depletion as simultaneous factors leading to the stagnation and eventual destruction of a number of Middle Eastern industries. An increasing gulf between the poor and the rich may have geared Middle Eastern manufacturing towards specializing in intricate luxury items for the latter at the cost of mass producing simpler goods for the common masses. Indeed, it was Europe's ability to mass produce cheaper goods, such as cloth, that permitted it to flood Middle Eastern markets with its exports from a relatively earlier period than is generally assumed (ca. 13th c.).

The Middle East was superior to the West in production and technological innovation from the seventh to the eleventh century, but thereafter the trend was reversed. This brief essay attempts no definitive explanation for this phenomenon, it only suggests some directions for expanding future research with an eye to re-orienting the methodological perspective of Middle Eastern historians. Material and socioeconomic forces interact in creating a dynamic whole and scholars must be aware of both, for only then can they hope to write a truly "wholistic" and seamless history of the Middle East.

#### NOTES

<sup>1</sup> For an excellent discussion on the above points the reader is strongly urged to see the forthcoming article by Nikki R. Keddie, "Material Culture and Geography: Towards a Holistic Comparative History of the Middle East", in the Fall 1984 issue of *Comparative Studies in Society and History*. Profound thanks are expressed to the author for the use of her original manuscript, and for her well appreciated guidance and support.

<sup>2</sup> The reader should also be aware of Watson's earlier published articles which were the genesis of the above quoted book. Please see "The Arab Agricultural Revolution and its Diffusion, 700-1100," *Journal of the Economic and Social History of the Orient*, 34(1974), 8-35; and "A Medieval Green Revolution: New Crops and Farming Technique in the Early Islamic World", in A. Udovitch, ed., *The Islamic Middle East 700-1900: Studies in Social and Economic History* (Princeton, 1981).

<sup>3</sup> Watson, *Agricultural Innovation...*, 4.

<sup>4</sup> *Ibid.*, 129.

<sup>5</sup> Ibid., 131.

<sup>6</sup> The reader should consult Claude Cahen, "Notes pour une histoire de l'agriculture dans les pays musulmans," *Journal of the Economic and Social History of the Orient*, 14(1972), 63; "Quelques mots sur les hilaliens et le nomadisme", Ibid., 11(1968), 130-133; and "Nomades et sédentaires dans le monde musulman du moyen âge", in D.S. Richards, ed., *Islamic Civilization 950-1150* (Oxford, 1973), 93-104. For an opposite view, that of decline from the very beginning, see A. Ashtor, *A Social and Economic History of the Near East in the Middle Ages* (Berkeley and Los Angeles, 1976).

<sup>7</sup> A number of references to "Islamic" applications of waterpower for industrial purposes are found in Bernard Rosenberger, "Les vieilles explorations minières et les anciens centres métallurgiques du Maroc", *Revue de géographie du Maroc* 18(1970), 59-102; and Paul Berthier, *Les anciennes sucreries du Maroc et leurs réseaux hydrauliques* (Rabat, 1966), 39. For a longer and more definitive description of waterwheels and their uses in the Middle East, the reader should consult Thorkild Schioler, *Roman and Islamic Water-Lifting Wheels*, Acta Historica Scientiarum Et Medicinalium Editio Bibliotheca Universitatis Hauniensis, 28(Rome, ?).

<sup>8</sup> For a good overview of Islamic engineering and machine designs see Donald Hill, "A Treatise on Machines by Ibn Mu'ādh Abū 'Abd Allāh al-Jayyānī", *Journal for the History of Arabic Science*, 2(1978) 33-46; Ahmad al-Hassan, "A Compendium on the Theory and Practice of the Mechanical Arts," Ibid., 1(1977)47-64; and D. Hill, "The Banu Musa and Their Book of Ingenious Devices", *History of Technology*, 2(1977) 39-76.

<sup>9</sup> Hill, "...al-Jayyānī," 39.

<sup>10</sup> Fernand Braudel, *Capitalism and Material Life* (New York, 1973), 266.

<sup>11</sup> See Thomas Glick, *Islamic and Christian Spain in the Early Middle Ages* (Princeton, N.J., 1979), 218-219.

<sup>12</sup> S. Lilley, *Men, Machines and History* (London, 1948), 48; and Braudel, *Capitalism and Material Life*, 280. 13. A number of sources bear this out, for the present reader see J. Piatkowski, "Metallurgical Examination of two Damascene Steel Blades," *Journal for the History of Arabic Science*, 2(1978) 3-30; and Ahmad al-Hassan, "Iron and Steel Technology in Medieval Arabic Sources," Ibid., 31-52.

<sup>14</sup> Rosenberger, "Explorations Minières...", 66.

<sup>15</sup> Berthier, *Sucreries...*, 39.

<sup>16</sup> Keddie, "Material Culture..."

<sup>17</sup> Ibid.

<sup>18</sup> E. Ashtor, "Levantine Sugar Industry in the Late Middle Ages: A case Study of Technological Decline," in Udovitch, *The Islamic Middle East*.