MINING

Late Antiquity to Early Islam

By

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PRODUCTION

The exploitation of natural resources and the conversion of raw materials into manufactured products are fundamental economic activities. The main difference between the world of Late Antiquity and that of early Islam in terms of economic production appears to be, in the latter case, more intensive and extensive exploitation of mineral and water resources, of land for agriculture and domestic animals, and of animal and human labor, increased specialization in manufacturing and services, and a greater commercialization of production. This is basically the difference between a stable or retracting economy and an expanding economy. It is useful to begin the discussion of these changes with a consideration of the extraction of minerals.

a. Mining[1]

The mining of metallic ores and the quarrying of stone provided much of the raw material for manufacturing and building. By the late Roman period there had been a marked retraction of mining throughout the Mediterranean caused by growing insecurity, barbarian invasions, labor problems, and the depletion of ancient mines. Although an imperial decree of 365 had encouraged private mining,[2] Lombard argues that the main reason for the decline in mining production was the late Roman social structure. As the frontiers of the Empire stabilized and then contracted there were fewer slaves

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[1] This section has profited from the generousity of Patrice Cressier, Casa de Velázquez, Madrid, of Carol Meyer, and the comments of Donald Carlisle, Department of Geology, UCLA.

[2] Codex Theodosianus, X, 19, 3; S. Vryonis, "The question of the Byzantine mines," Speculum, 37 (1962), p. 2.

available so the workers in the mines were treated as slaves hereditarily tied to that occupation.[3]

As later exploitation reveals, significant mineral resources remained in the western Mediterranean, but it has generally been assumed that mining was interrupted at the beginning of the barbarian period[4] and revived in Iberia under the Muslims.[5] Recent archaeology has shown that, at least in some parts of Iberia, there was not only direct continuity from the late Roman to the Visigothic period at some mining sites,[6] but that there was an important resumption of mining and metallurgical activity in gold, silver, copper, and iron at centralized sites from the fifth or sixth cen-

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[3] M. Lombard, Les métaux dans l'Ancien Mond du V^e au XI^e siècle (Paris, 1974), p. 30. Slaves, convicts, Christians, barbarians, provincials, and even soldiers were employed in ancient Roman mining. Miners were often chained with leg irons (J. F. Healy, Mining and Metallurgy in the Greek and Roman World, London, 1978, p. 135).

[4] Lombard, Les métaux, p. 31. The tin mines in Spain were closed in about 250 C. E. (p. 15). Lombard suggests that the hiatus in mining in the west created the possibility for a new start in Muslim Spain and North Africa, as well as in northwestern Europe. According to O. Puche Riart and J. Bosch Aparicio, "Apuntes sobre la minería visigótica hispana," in Actas de las I Jornadas sobre minería y tecnología en la Edad Media peninsular (León, 1996), pp. 206-7, there is no real evidence of tin mining in Iberia after the fourth century C. E.

[5] Y. Cosin Corral, "Un ejemplo de minería islámica: la ciudad hispano-musulmana de Vascos (Navalmoralejo, Toledo)," in Arqueologia e historia de la Minería y Metalurgia (Madrid, 1996), p. 107.

[6] P. Grañeda Miñón, et al., "La minería medieval al sur del Sistema Central: Madrid y su entorno," in Actas de las I Jornadas sobre minería y tecnología en la Edad Media peninsular (León, 1996), pp. 250, 256.

tury until the end of the Visigothic period.[7] Mines in Visigothic Iberia belonged to the government and may have been operated as royal concessions.[8]

In the eastern Mediterranean and western Asia ancient mining had virtually exhausted the oxidized ores found near the surface.[9] Still, there were important sources of gold, silver, lead, iron, and copper in eastern Pontus, the Taurus and Caucasus mountains and Armenia in the sixth and seventh centuries,[10] a border region over which the late Romans and Sasanian Persians fought.

At the same time an intensification of silver mining is associated with the late Sasanians, exemplified by coins and silver objects,[11] across northern Iran, in Central Asia and in Arabia, that continued into the Islamic period. There is archaeological evidence for a distinct increase in the exploitation of Central Asian silver mines at the end of the sixth and during the seventh cen-

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[7] Ibid., pp. 252, 256; M. Bertrand, et al., "Mines et metallurgies medievales de la Sierra Nevada (región de Guadix, prov. de Grenade). Premières Données," in Actas de las I Jornadas sobre minería y tecnología en la Edad Media peninsular (León, 1996), p. 182. According to Puche Riart and Bosch Aparicio, "minería visigótica," pp. 200-10, iron, lead, silver and gold were mined but there is little evidence of copper or mercury mining in Visigothic Iberia.

[8] Puche Riart and Bosch Aparicio, "minería visigótica," pp. 214-15.

[9] Lombard, Les métaux, p. 32; J. Hester, et al., "Preliminary Report on the Third Phase of Ancient Mining Survey, Southwestern Province --1403AH 1983," Atlal, 8(1404/1984), pp. 130, 137.

[10] J. Haldon, Byzantium in the Seventh Century: the transformation of a culture (Cambridge, 1990), p. 13; Vryonis, "Byzantine mines," p. 3.

[11] Lombard, Les métaux, pp. 44, 236.

tury, that peaked in the ninth and tenth centuries.[12] Al-Hamdani, writing in the tenth century, tells of a silver and copper mine at the village of Shamam in the Najd, where at least one thousand Majus[13] worked in the mine, and which had been prosperous before Islam and during most of the Islamic period, but was in ruins by the tenth century.[14] The Sasanian occupation of Yaman in the 670s appears to be connected with the development of silver mining there. A report that the Ethiopians lent silver to the Himyarite kings of Yaman suggests that the latter lacked it,[15] while the account that Wahriz, the conqueror and first Sasanian governor of Yaman, sent a caravan with the wealth of Yaman to the Persian monarch that included silver ingots and jewels[16] suggests that silver had become available. According to al-Hamdani the traces of the work of pre-Islamic miners at the famous silver mine of ar-Radrad in the Yaman were more numerous than those of Islamic times, and he says that the miners were all Persians who had arrived

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[12] Ibid. pp. 43, 239.

[13] I.e. Zoroastrians.

[14] D. M. Dunlop, "Sources of Gold and Silver in Islam According to al-Hamdani," Studia Islamica, 8 (1957), p. 40; al-Hamdani, Kitâb al-Jawharatayn al-ʿatîqatayn al-maʾiʿatayn min as-safra' wa 'l-bayda', ed. and tr. C. Toll, Die Beiden Edelmetalle Gold und Silber (Uppsala, 1968), pp. 142-3.

[15] M. Piotorvski, "L'économie de l'Arabie préislamique," in S. Noja, ed., L'Arabie avant l'Islam (Aix-en-Provence, 1994), p. 233.

[16] Tabari, Ta'rikh, I, 984.

before Islam[17] and in the time of the Umawis and ʿAbbasis. This mine was abandoned in 883.[18]

In general, the new mining associated with the Islamic period continued to work older sites.[19] But, since the oxidized ores near the surface had been removed by ancient miners, it was necessary to dig deeper[20] for lode deposits of sulfide ores and quartz veins, that required more effort and more sophisticated methods to extract the metal.[21] Although mining technology varied from one mineral to another and from one region to another, and while in any single region technologies might range from primitive to highly developed, and different forms of organization might co-exist,[22] mining in the

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[17] This would have to have been after the occupation of the Yaman by the Sasanians in the late sixth century. The silver output of this mine may have contributed to the vast increase in coinage under Khusraw II.

[18] Dunlop, "Gold and Silver", pp. 40, 41, 43; al-Hamdani, Jawharatayn, pp. 142-45, 148-49.

[19] P. de Jesus, et al., "Preliminary Report of the Ancient Mining Survey 1981 (1401)," Atlal, 6 (1402/1982), p. 79; A. Kisnawi, et al., "Preliminary Report on the Mining Survey, North-West Hijaz (1402/1982)," Atlal, 7 (1403/1983), p. 77; Lombard, Les métaux, p. 156.

[20] Kisnawi, "Mining Survey," p. 78 notes that shafts are almost always present at Islamic period sites in Arabia. Mine shafts themselves, of course, were not new. The use of sloping adits, shafts with galleries, and ventilation goes back to the Bronze Age (second millennium B.C.E.). See Healy Mining and Metallurgy, p. 70.

[21] According to Healy (Mining and Metallurgy, p. 258) the Romans had begun to obtain gold as a byproduct from processing pyrites and sulfides from the first century C.E.

[22] P. Cressier, "Observationes sobre fortificación y minería en la Almería islámica," in A. Malpica, ed., Castillos y Teritorio en al-Andalus, p. 490; A. Y. Al-Hassan and D. R. Hill, "Maʿdin," EI (2), V, p. 968.

early Islamic period is distinguished by the wider application of methods such as the mercury amalgamation process to extract gold from crushed quartz vein deposits,[23] cupellation to extract silver from argentiferous lead ores (galena) and to separate gold from copper and lead ores, cementation to separate gold from silver, and the use of bellows inserted in ceramic tubes built into the furnace wall to maximize the heat. The use of nitric acid to separate gold from silver (parting) appears to be an innovation of the Islamic period.[24] A good example of activity on the Arabian Shield is the copper-mining site at an-Nuqrah, where, after many shafts were dug in surface outcrops, it turned into an open pit mine. After the ore was crushed in diorite socket grinders near the mine, it was sent to the smelters.[25] Small diorite socket grinders are ubiquitous at pre-Islamic and Islamic mining sites in Arabia, but cupel-shaped slag is found only at Islamic gold-mining sites.[26] These methods were clearly labor- and energy-intensive, but enabled the

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[23] This method was known to the elder Pliny, Historia Naturalis, XXXIII, vi. See also Healy, Mining and Metallurgy, pp. 153, 157; and Lombard, Les métaux, pp. 204, 242. Amalgamation was probably not used by the Romans in active metallurgy.

[24] Al-Hassan and Hill, "Maʿdin," p. 970; Hester, "Ancient Mining," p. 129; Kisnawi, "Mining Survey," p. 78. Cupellation seems to be the oldest, most efficient way to separate precious metals from a base. In antiquity gold alloyed with lead was oxidized in a crucible. Cementation was known to Strabo (Healy, Mining and Metallurgy, pp. 152, 155).

[25] de Jesus, "Ancient Mining," p. 65.

[26] de Jesus, "Ancient Mining," p. 66; Kisnawi, "Mining Survey," p. 78-9. Hester ("Ancient Mining," pp. 129, 134, 137) argues cogently that the grindstones found in association with mining settlements were more likely to have been used in food preparation than to crush ore, but there is literary testimony for the latter in Ptolemaic Egypt (see below).

extraction of metal from previously unexploitable ores.[27] The early Islamic period saw an expansion of mining for gold, silver, copper, iron, lead, and steatite.

Gold was still being produced in the mountains of Armenia in Late Antiquity, and the Byzantines and Sasanians competed over its control. The Persians had leased these gold mines from the Byzantines in 421, and did not wish to return them or the miners they had hired from the Romans. There were also "gold-streaming mountains" in Armenia, where torrents of rain washed up gold nuggets (placer gold), which people leased from both the Byzantines and Sasanians for two hundred pounds of gold. Anastasius (491-518) seized these mountains and the Byzantines got the gold. In the same period, the gold mine at Pharangium, in Armenia, was worked by a native named Symeon with the permission of the Sasanian ruler, Kubad I. Symeon went over to the Romans in 530, but refused to deliver the gold to either side.[28]

Western Arabia had also been an important source of gold in antiquity.[29] One of the advantages of gold is that it does not oxidize, although oxidized ores can contain native gold. But nuggets and gold flakes were washed down with the sand in wadis and in some places there were exposed veins of gold. These sources had

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[27] Lombard, Les métaux, p. 242.

[28] Socrates Scholasticus, Ecc. Hist. (1904), 7.18; Vryonis, "Byzantine mines," pp. 5-6. In a similar vein, Sebeos reports that the emperor Heraclius granted the salt mine at Koghb to the Armenian catholicos in the early seventh century. See Robert Bedrosian, Sebeos' History (New York, 1985), p. 117.

[29] Lombard, Les métaux, p. 21.

been virtually exhausted by ancient miners in Arabia leaving quartz outcroppings and veins as the next best source of gold. But this required a different technology such as digging shafts and crushing and processing the ore. There is some evidence that this had already begun in pre-Islamic Arabia. There are shafts on quartz veins at two mining sites in the Ta'if region that appear to be pre-Islamic.[30]

There is even more evidence of a dramatic increase in gold mining on the Arabian Shield in Islamic times. Of twenty-nine gold mines and mining settlements identified in the north-west Hijaz, twenty sites belong to the Islamic period. For Kisnawi the way numerous gold mining settlements are clustered around a central site, such as Umm Qarayyat east of al-Wajh, suggests a degree of organization; the very number of sites suggests a real commitment to gold production.[31] One of these sites has a Kufic inscription dated 750 C.E.[32] In the central Hijaz, of eleven ᶜAbbasi-period mining sites in the Nuqrah region, halfway between Burayda and Madina, seven are gold mines and four are copper mines, and de Jesus draws the same conclusion as Kisnawi about commitment to the exploitation of copper and gold on the Arabian Shield in ᶜAbbasi times.[33] One of these sites, al-Koom al-Gharbi, has pits dug down into the quartz outcroppings on the surrounding hills. This site

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[30] J. Zarins, et al., "Preliminary Report on the Central and Southwestern Provinces Survey: 1979," Atlal, 4 (1980), p. 28.

[31] Kisnawi, "Mining Survey," pp. 77, 81-82.

[32] K. S. Twitchell, Saudi Arabia (Princeton, 1947), pp. 159f.

[33] de Jesus, "Ancient Mining," p. 63.

and ash-Shumta' I have a row of one-roomed structures said to be typical of ᶜAbbasi-period gold mining settlements. However, two other sites (Mawan and Sukhaybarat al-Gharbiyah) have stone houses with one, two, or three rooms.[34] The famous gold mining complex at Maᶜdin Bani Sulaym (Madh adh-Dhahab) between Rabadha and Ta'if saw pre-Islamic activity and was known in the time of Muhammad.[35] The miners belonged to the Banu ᶜUsayya and the Banu Farran ibn Bali and there is a reference to a dispute between the owners of the mine and the Banu Farran miners. The wealthy Hajjaj ibn ᶜIlat al-Bahzi is said to have owned the gold mines in the territory of the Banu Sulaym. In the time of ᶜUmar ibn al-Khattab there was a dispute over the ownership of Maᶜdin Bani Sulaym between the Sulaym and the Bali.[36] There is blue ᶜAbbasi-period pottery at one of the mining sites on the east side of the mountain there.[37] In the southern Hijaz, there are three ᶜAbbasi-period sites where gold and silver were mined in the Dawadami region. Two other ᶜAbbasi-period sites in the Zulam region may also have been occupied in pre-Islamic times. In addition there is a typical ᶜAbbasi-period mining camp at Sirr Ba'l, 25 km. north-east of Wadi Tathlith, with about 30 rectangular structures, of one or two rooms each, clustered in a

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[34] Ibid., pp.77-8.

[35] Dunlop, "Gold and Silver," p. 32; S. al-Rashid, Rabadhah (Riyad, 1986), pp. 5, 14; Zarins, "Central and South Western Provinces," pp. 28-9. Ibn Rustah says that the village at Maᶜdan Bani Sulaym was ancient (al-Aᶜlaq an-Nafisa, Leiden, 1891, p. 149).

[36] M. Lecker, The Banu Sulaym. A Contribution to the Study of Early Islam (Jerusalem, 1989), pp. 198-201.

[37] Zarins, "Central and South Western Provinces," pp. 28-9.

small valley less than 500 m. from the mining operations. The hillside east of this settlement has open cuts and smaller vertical shafts in large exposed quartz veins.[38]

There were also gold mines in the Yamama region of the Najd in the ninth and tenth centuries. It is not known how long these mines had been worked by Arabs of the Rabi°a, Mudar, and Tamim tribes ("the people of the gold mines"), but when the Banu al-Ukhaydir took over the Yamama in 852, they expelled these tribes to Egypt (they were most of the population of the Yamama), appropriated the gold mines for themselves, and imported slaves to work the farms and mines of those who left. This caused a mass exodus of thousands of miners who relocated to the region between the Nile and Red Sea and went to work at the gold mines at Wadi al-°Allaqi,[39] that had just been reopened. Evidently gold continued to be mined in the Najd, because al-Hamdani mentions some eleven gold mines currently being worked there in the tenth century, but he also notes the existence of unworked mines in the camping grounds of bedouin Arabs in the Peninsula.[40]

In South Arabia al-Hamdani identifies some five gold mines that were being worked in his own time, in the tenth century, in the Tihamah, al-Yaman, and Shahr. One of them, at Dankan, between

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[38] Zarins, "Central and South Western Provinces," pp. 27-8, 34.

[39] °A. Al-Askar, "History of the Banu Al-Ukhaydir Dynasty in Al-Yamama," Dirasat, 23 (1996/1417), p. 365; Ibn Hawqal, Kitab Surat al-Ard (Leiden, 1938), I, pp. 31, 53.

[40] Dunlop, "Gold and Silver," pp. 37-9; al-Hamdani, al-Jawharatayn, pp. 136-41.

the territory of the Kinana and the Azd, had been recently discovered by chance (possibly exposed by a flood) and appropriated by the government and the people.[41] He gives a contemporary description of gold mining operations: narrow pits were dug, like a series of communicating wells, becoming wider as they descended down as far as the water table. The ore was brought out of the pit, separated from gravel (a typical underground placer), and washed in a wooden trough with two or three partitions. When the trough was agitated, the earth washed out leaving particles of gold that were collected, sifted in a small vessel and rinsed out with water into a dish where they were covered with an equal amount of mercury and the whole covered with water. This was then scraped into an earthenware pot and poured through a coarse rag, leaving the amalgam of gold and mercury that was roasted until the mercury evaporated.[42]

Outside of Arabia, there is no evidence that most of the ancient gold mines of Nubia and Ethiopia ceased to operate during Late Antiquity. Lombard argued that Byzantine access to them was cut off from the fourth century by the Blemmyes.[43] But the Byzantines defeated the Blemmyes in 452 C.E. and imposed a hundred years' peace on them, and in 535 C.E. the Blemmyes were decisively

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[41] Dunlop, "Gold and Silver," pp. 37-8; al-Hamdani, al-Jawharatayn, pp. 136-9.

[42] Dunlop, "Gold and Silver," pp. 44-5; al-Hamdani, Jawharitayn, pp. 150-53.

[43] Lombard, Les métaux, pp. 21-2, 126.

defeated by the Nobades.[44] There is actually evidence for Byzantine gold mining in the Eastern Desert of Egypt, in the western part of the Arabian-Nubian Shield, where geological conditions are similar to those in western Arabia, and gold occurs in quartz veins in the granite and in sulfide minerals. Oxidized gold-bearing quartz veins had been mined since antiquity, and in the second century B.C.E. the quartz veins were first roasted with a hot fire to make them crumbly, worked by hand, and the quartz rock crushed with sledge hammers. The ore was then pulverized in stone mortars with iron pestles and ground to the consistency of flour between rotary millstones.[45]

An impressive Byzantine gold-mining settlement has been identified at Bir Umm Fawakhir, halfway between the Nile and the Red Sea coast and about five kilometers northeast of the Wadi Hammamat, dated to the fifth and sixth centuries and possibly lasting into the seventh.[46] There are also gold mines in the Wadi Attala north of Bir Umm Fawakhir that were occupied in the

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[44] C. Meyer, "Gold, Granite, and Water: The Bir Umm Fawakhir Survey Project 1992," in W. Dever, ed., Preliminary Excavation Reports: Sardis, Bir Umm Fawakhir, Tell el-ᶜUmeiri, The Combined Caesarea Expeditions, and Tell Dothan. The Annual of the American Schools of Oriental Research, 52 (1995), p. 89.

[45] Ibid., pp. 44-6, 56; Healy, Mining and Metallurgy, pp. 84-5. It is estimated that mills could produce about four tons of ore in 24 hours, but Healy (p. 142) remarks that this was more effective for sulfide than for gold-quartz ores. Fire does not seem to have been applied to quartz veins in Islamic mining.

[46] Ibid., pp. 37, 61; Eadem, "A Byzantine gold-mining town in the eastern desert of Egypt: Bir Umm Fawakhir, 1992-93," Journal of Roman Archaeology, 8 (1995), p. 192.

Byzantine period.[47] Gold may have been mined at Wadi al-ʿAllaqi, east of Aswan, by the Byzantines, since the traces of work by the Rum were noticed there in the ninth century.[48]

The mines at Bir Umm Fawakhir consist of open trenches that follow quartz veins from the surface and vertical, inclined, or horizontal workings sunk into the mountainside. Some workings have stone platforms at the mouth.[49] A granite crushing block found at the entrance to a mine surrounded by chunks of quartz suggests that the ore was reduced at the mouth of the mine[50] Concave granite grinding stones and rotary granite millstones found at the site were presumably used to reduce the ore to powder, which was then probably washed and the gold dust taken to the Nile Valley for final purification.[51] Thus the process would have used water but no fuel at the site. The low-grade ore from these mines yields only two to three grams of gold per ton compared to five to seven grams per ton from the ancient and modern mines about four kilometers to the southeast in the Wadi el-Sid. That such mines were exploited during the fifth and sixth centuries may reflect a

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[47] Meyer, "Byzantine gold-mining town," p. 197.

[48] Ibn Hawqal, Surat al-Ard, I, p. 53. Gold was mined at Wadi al-ʿAllaqi by the ancient Egyptians. The Turin papyrus (1250 B.C.E) contains a map of the mines there (Healy, Mining and Metallurgy, p. 70, Pl. 7.

[49] C. Meyer and M. Omar, "The Geological Context of Bir Umm Fawakhir," Proceedings of the Egyptian-Italian Seminar on Geosciences and Archaeology in the Mediterranean Countries, Cairo, November 28-30/1993 (Cairo, 1995), pp. 499-500.

[50] Ibid.

[51] Ibid.; Meyer "Gold, Granite, and Water," pp. 54, 56-7.

greater demand for and higher value of gold, and/or that more productive mines had been exhausted or were no longer available.[52]

There are the remains of over 200 houses at Bir Umm Fawakhir strung out or clustered along the wadi bed. Most are two- or three-room structures (possibly family units), and sometimes two or more such units are clustered into a larger building. The haphazard, separate, and uncrowded siting of the houses led Meyer to see no evidence of "central planning or regimented, military orderliness, much less of cramped, mean, slave quarters."[53] The population in the main settlement is estimated at a little over 1000,[54] and, judging from the presence of pottery bowls with crosses stamped on them, at least some of people there were Christian.[55]

However, there does appear to have been a hiatus in gold mining in the Eastern Desert at some time in the seventh or eighth century. When the Muslim governor of Egypt, ʿAbd Allah ibn Abi Sarh, conquered Aswan in 652, the only advantage Ibn Hawqal notes is that one could travel to the Hijaz from there.[56] The road does go by Wadi al-ʿAllaqi, but the mines are not mentioned in this context. Gold mining had revived by the ninth century, which saw intense activity in the mines along the upper Nile, particularly those of Wadi al-ʿAllaqi, in the desert between Aswan on the Nile

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[52] Meyer, "Byzantine gold-mining town," p. 199; Meyer and Omar, "Geological Context," p. 499.

[53] Meyer, "Gold, Granite, and Water," pp. 53-4.

[54] Meyer, "Byzantine gold-mining town," p. 214.

[55] Meyer, "Gold, Granite, and Water," p. 55.

[56] Ibn Hawqal, Surat al-Ard, I, p. 50.

and ʿAydhab (ancient Berenike) on the Red Sea.[57] Some of the men in the punitive campaign of ʿUbayd ibn Jahm against the Beja of the Eastern Desert in 847 immediately noticed the gold and the traces of Byzantine gold mining there and returned in the same year. The rediscovery of the gold mines coincided with the invasion of the Yamama by Muhammad ibn Yusuf al-Ukhaydir in 852 and the resettlement of thousands of gold miners of the Banu Rabiʿa and Mudar at Wadi al-ʿAllaqi, which they took over from people from the Hijaz.[58] According to Ibn Rustah most of the people there belonged to the Rabiʿa of the Banu Hanifa from the Yamama.[59] The ninth-century geographer, al-Yaʿqubi, describes Wadi al-ʿAllaqi as a huge town, very populous with all kinds of people, Arabs and non-Arabs, all of whom were gold prospectors. It was a very commercial town provided with markets and merchandise. Merchants and non-merchants alike had Negro slaves who worked the mines, and the ore was apparently rich in arsenic sulfide (az-zarnikh al-asfar), and, after it was extracted, it was smelted.[60]

Wadi al-ʿAllaqi was the center of a gold-mining region. All

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[57] Al-Hassan and Hill, "Maʿdin," p. 967; Lombard, Les métaux, p. 203.

[58] Ibn Hawqal, Surat al-Ard, I, pp. 31, 53. Wadi al-ʿAllaqi was also a stop on the pilgrim road from Aswan to ʿAydhab. After 859 the authority of the ʿAbbasi caliph was no longer recognized at Wadi al-ʿAllaqi, and after the death of al-Mutawakkil, the Beja took over the environs of the town (Ibid., p. 54). See also p. 162.

[59] Ibn Rustah, al-ʿAlaq an-Nafisa, p. 334.

[60] Ibn Rustah, al-ʿAlaq an-Nafisa, p. 334, al-Yaʿqubi, Kitab al-Buldan (Leiden, 1892), p. 334. This is virtually the same text. The ore was probably arsenopyrite, which frequently occurs with gold; the Romans had known how to extract gold from it (Healy, Mining and Metallurgy, pp. 42, 156).

the places along the route there from Aswan were gold mines, and Ibn Rustah identifies some eleven gold mining sites in its vicinity, one of them settled by the Rabi°a from the Yamana, another by the Bali and Juhayna, and a third by the Banu Sulaym and others of Mudar.[61] There were merchants of the mines at Aswan,[62] and gold was exported from °Aydhab.[63] The mines at Wadi al-°Allaqi still belonged to the Banu Rabi°a in the tenth century, and the wealth was sent to Egypt[64] via Aswan; al-Hamdani mentions that they produced excellent gold-dust.[65] Idrisi, in the twelfth century, adds that mercury amalgamation was used to extract the gold from its ore, and that the prospectors bought and sold what they had recovered with each other, while merchants transported the gold away.[66] What appears to have been fairly free private enterprise changed under the Fatimis (late tenth to late twelfth centuries) when agents of the caliph themselves directed the gangs of slaves working in the mines.[67] Al-Hamdani identifies some nine additional mines in Ethiopia, Nubia, and Upper Egypt that were apparently in operation

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[61] Ibn Rustah, al-°Alaq an-Nafisa, pp. 334-5, al-Ya°qubi, Kitab al-Buldan, p. 334.

[62] al-Ya°qubi, Kitab al-Buldan, p. 334.

[63] Ibn Rustah, al-°Alaq an-Nafisa, p. 335

[64] Ibn Hawqal, Surat al-Ard, I, p. 50.

[65] Dunlop, "Gold and Silver," p. 40; al-Hamdani, al-Jawharatayn, pp. 142-3.

[66] Lombard, Les métaux, p. 204.

[67] Ibid.

in the tenth century.[68] Ibn Hawqal mentions gold mines of excellent quality west of the White Nile, but he also notes that there were rich gold mines in Nubia that no one exploited lest they become known and the Muslims take them over.[69]

It is debatable whether gold was exported from East Africa to western Asia during Late Antiquity. In any case, the usual image is of baskets of gold dust transported from the interior to the coast and traded to Persian and Umani merchants via Sofala and the ports of the northern Swahili coast in the Islamic period. The use of more advanced mining technology by the tenth century is indicated by the report of Ismailwayh the Umani in 922, who described the gold mines in the Sofala region where the miners "excavated in galleries like ants."[70] Since, according to Idrisi, in the twelfth century, the East Africans did not know of the mercury amalgamation process,[71] they may still have been mining rich veins of coarse visible gold.

There were also sources of gold in eastern Iran and Central Asia. Ibn Hawqal reports that there was a little gold in Juzjan,[72] and that many people said there were gold mines on the mountain of Nuqan between Nishapur and Tus, but their exploitation was not

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[68] Dunlop, "Gold and Silver," p. 40; al-Hamdani, Jawharatayn, pp. 142-3. At least the assumption that they were operating is based on his practice of noting which mines were not being worked.

[69] Ibn Hawqal, Surat al-Ard, I, pp. 58-9.

[70] M. Tampoe, Maritime Trade between China and the West (Oxford, 1989), p. 151.

[71] Lombard, Les métaux, p. 202.

[72] Ibn Hawqal, Surat al-Ard, I, 162.

profitable.[73] However, a gold mine opened at Khashbaji in Sistan in 1000 C.E. is said to have been as productive as the silver mines at Panjhir.[74] According to Ibn Hawqal the gold, silver, and mercury mines of Central Asia were the richest in the Islamic world. Mines of silver and gold existed in the mountains stretching from Ghur across Khurasan, to Bamiyan as far as Panjhir, in the land of Wakhkhan, and past Shash to the Khirkhiz. The most productive deposits were found near the Khirkhiz and in the territory of Farghanah and Ushrushanah, which, when exploited, were more productive than the silver mines of Panjhir.[75] The silver and gold mines on Mt. Kuhak near Samarqand were difficult to work, but there was gold and much gold-bearing sand in the river valleys of al-Khuttal brought down by the torrents flowing from Wakhkhan.[76] There were gold mines in the mountains of al-Buttam, east of Sughd,[77] and gold and silver mines at Ilaq, near Shash, in the mountains that stretched to Farghanah. There was also a mint for gold and silver coins at Ilaq,[78] and here one should note the presence of a mint near the mines.

At the other end of the early Islamic world gold mining continued from the Visigothic period in Muslim Iberia under the

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[73] Ibid., II, 434.

[74] Al-Maqdisi, Kitab al-Bad' wa'l-ta'rikh (Paris, 1899-1919), IV, 78.

[75] Ibn Hawqal, Surat al-Ard, II, 445, 464.

[76] Ibid., II, 475-6.

[77] Ibid., II, 505.

[78] Ibid., II, 509-10.

Umawis (until 1030). There was placer mining on the banks of the Segre, Ebro, Genil, and Darro rivers and at the mouth of the Tajo, and gold mines in the regions of Tudmir (Murcia) and Elvira (Granada).[79]

West Africa has historically been one of the most important sources of gold, and was opened up to Muslim commerce by Ibadi merchants in about 800. Al-Hamdani describes Ghana as having the most productive gold mine in the world with veins, lodes, strips, laminae, and tongues of gold just lying about ready to be picked up and carried off.[80] Be that as it may, the fact that Idrisi reports that the West Africans knew of the mercury amalgamation process suggests that gold was being extracted from some ore at least by the twelfth century if not before.[81]

Despite some evidence that new forms of mining had appeared in Arabia shortly before Islam, it would seem that gold production peaked there in the ninth and tenth centuries. Processing the ore required water, mercury, and some fuel to roast the amalgam, and seems to have been done in rather small batches, which made it very labor intensive. It appears to have been worth the effort. It should also be noted that there are no mints associated with the gold mines in Arabia or Upper Egypt.

Silver was usually extracted from argentiferous lead ore

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[79] R. Arié, Études sur la civilisation de l'Espagne musulmane (Leiden, 1990), pp. 248-9; Cosin Corral, "Vascos," p. 108.

[80] Dunlop, "Gold and Silver," pp. 39-40; al-Hamdani, al-Jawharatayn, pp. 140-43. For West African gold see Lombard, Les métaux, pp. 208-28.

[81] Lombard, Les métaux, pp. 202-3.

(galena, lead sulfide).[82] Al-Hamdani's comment that the location of silver mines is indicated by the presence of antimony (kohl, stibnite) on the surface[83] is at least plausible. Antimony does occur with silver in metal-bearing veins, and Pliny says that antimony was found in silver mines.[84] As al-Hamdani describes the process of extracting silver from galena in the Yaman, the ore was broken up into particles the size of large raisens, which were crumbled together with water and enough "yellow clay" to bind it. A furnace was built equipped with one or two pairs of bellows and with a vent at the back and a gutter leading to a tank. The vent was blocked and the furnace filled with layers of mimosa wood and ore. Sometimes the heavy mimosa wood was mixed with lighter gum-acacia and juniper in order to burn more easily. The furnace was lit, and two men were assigned to work each pair of bellows. Often a wall was built between the bellows and the furnace because of the powerful effect lead vapor has on the brain. When the metal had formed in the bottom of the furnace, it was allowed to cool, and the vent was opened letting the lead flow into the tank and form an ingot. The lead was then placed in a dish (shaped cupel), juniper wood put on it and lit, forming lead oxide (litharge) and leaving the silver in the middle. According to al-Hamdani the ratio

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[82] Al-Hassan and Hill, "Maʿdin," p. 970; N. Lowick, "Silver from the Panjhir mines," Metallurgy in Numismatics, 2 (1988), p. 70.

[83] Dunlop, "Gold and Silver," p. 37; al-Hamdani, al-Jawharatayn, pp. 128-9.

[84] Healy, Mining and Metallurgy, pp. 35, 42, 259.

of silver to lead varied from one-half to one-sixth.[85] In Central Asia in the ninth and tenth centuries after the litharge was removed the silver was purified further by cupellation, in which the molten metal was heated in a small crucible usually containing bone ash. This extracted most of the rest of the lead, usually leaving about 1% of lead in silver coins from Central Asia.[86]

The ancient silver mines of the Cyclades, Macedonia, and Thrace had been exhausted by Roman times.[87] Silver resources existed in Iberia and the Moroccan Atlas during Late Antiquity, but the most important Byzantine centers of silver production were in Armenia and the Taurus mountains from the fifth to the seventh century.[88] There were also important silver resources in the zone of argentiferous mountains stretching from the Caucasus and Azerbayjan in the west across northern Iran to Khurasan and Central Asia in the east with less important sources in Fars and Kirman.[89] Lombard assumes that these resources must have been exploited under the Sasanians to provide them with silver for coins and silver objects.[90] Although this is entirely possible, there is, so far, no direct evidence of silver mining in Sasanian Iran. It is also difficult to see how the Sasanians themselves could have been

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[85] Dunlop, "Gold and Silver," pp. 46-8; al-Hamdani, al-Jawharatayn, pp. 268-75.

[86] Lowick, "Panjir mines," p. 70.

[87] Lombard, Les métaux, p. 26.

[88] Ibid., p. 127.

[89] Ibid., p. 43.

[90] Ibid., pp. 44, 236.

responsible for the intensification of silver mining in Central Asia at the end of the sixth and during the seventh century noted above,[91] or how they could have profited from it.

According to Lombard the main silver producing regions in early Islamic times were the same as in antiquity. However, in identifying these regions as Central Asia, northern Iran, the Caucasus, Ural, and Taurus mountains, the Moroccan Atlas, and Iberia,[92] he overlooks Arabia.[93] The operation of silver mines in the Najd and the Yaman from the late Sasanian period through most of the ninth century has already been noted.[94] There is also a silver mining site near Dawadimi in the north-western Hijaz dated to 700-726 C.E.[95] As al-Hamdani describes the famous mine of ar-Radrad in the Yaman before it closed in 883, there was a large village at the mine with water sources and date-palms. Lines of camels went back and forth between it and al-Basra in ʿIraq, bringing provisions from al-Basra, and presumably transporting the silver thence. There were 400 smelting furnaces, and, according to one of the agents of Muhammad ibn Yaʿfur, who held the right of the government there, the mine produced a camel's-load of silver, amounting to 20,000 dirhams, in a week, or approximately one

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[91] See page 00 above.

[92] Lombard, Les métaux, pp. 235-41.

[93] He also omits the silver mines at Majanna, between Qayrawan and Tebessa, in Ifriqiyya, in the tenth century. See Ibn Hawqal, Surat al-Ard, I, p. 84

[94] See page 00 above.

[95] Kisnawi, "Mining Survey," p. 78.

million dirhams in a year. There were also independent miners there, without any responsibility or direction, who obtained much silver. According to one of the foreigners (ghuraba') who worked the silver the cost of production was one-quarter the total yield (i.e. the profit margin was 75%). Al-Hamdani compares this favorably to a silver mine in the territory of the Banu Madhij worked under Ibn Ziyad, the ruler of Zabid, where the cost of production was two-thirds the total yield (i.e. the profit margin was 33 1/3%) because of the trouble and difficulty. The mine at ar-Radrad closed in 883 because of insecurity. When the Banu Khawlan of the Ibn ar-Ruwayya and the Banu 'l-Harith rebelled against Muhammad ibn Ya'fur, some of the rebels attacked the people at ar-Radrad, killing and plundering them. The rest fled, scattered to different countries, or went to San'a', where they had high social status, houses, and estates. When the mine closed, the price of silver in San'a' doubled.[96]

Although a new silver mine was discovered in Armenia in the late eighth century, or in the early ninth century[97] al-Hamdani admits that most silver mines were in Khurasan and mentions mines near Nishapur, Tus, and Balkh.[98] Three other mines in Khurasan were located near Bamiyan, in the Badghis region north of Herat, and in

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[96] Dunlop, "Gold and Silver," pp. 41-4; al-Hamdani, al-Jawharatayn, pp. 144-51.

[97] R. Hovannisian, ed., The Armenian People from Ancient to Modern Times. The Dynastic Periods: From Antiquity to the Fourteenth Century (New York, 1997), I, p. 136; Vryonis, "Byzantine Mines," p. 6.

[98] Dunlop, "Gold and Silver," pp. 40-1; al-Hamdani, al-Jawharatayn, pp. 142-45.

Juzjan.[99] In the eighth century 30,000 Zoroastrians mined and refined a great amount of silver from a mountain in Khurasan, which they virtually controlled. But when the government tried to take it away from them and give it to others in the fourteenth year of al-Mansur (767 C.E.), they resisted and rebelled. They routed one army, but were defeated by a second army, that killed 20,000 of them and took the rest captive.[100] This may have been at a town called Jabal al-Fidda in the territory of Badhghis, on the route from Sarakhs to Harat, that was located on a mountain with a silver mine. The mine had ceased to be exploited by the tenth century because of the lack of firewood[101] (for smelting). Ibn Hawqal also reports a mountain with silver near Jiruft in Kirman in a range called "the mountains of the silver mine."[102]

But the most productive silver mines were those at Panjhir and Jarbaya, near Andarab, east of Balkh, in the Hindu Kush. These mines may have been worked in antiquity; in the early Islamic period the settlement of six thousand to ten thousand miners lasted at least three centuries and possibly much longer. As described

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[99] T. Lewicki, "Le commerce des Samanides avec l'Europe orientale et centrale à la lumière des trésors de monnaies coufiques," in Dikran K. Kouymjian, ed., Near Eastern Numismatics, Iconography, Epigraphy and History (Beirut, 1974), p. 231. Lewicki also notes a mountain of silver near Jiruft in Kirman.

[100] Agapius of Manbij, Kitab al-ʿUnwan, ed. L. Cheikho, Agapius Episcopus Mabbugensis Historia Universalis (Louvain, 1954), p. 377. This text is also in A. Vasiliev, Patrologia Orientalis, VIII (1912), pp. 544-45.

[101] Ibn Hawqal, Surat al-Ard, II, 441. This information is repeated by Idrisi (Lombard, Les métaux, p. 238).

[102] Ibn Hawqal, Surat al-Ard, II, 309.

in the tenth century, the veins of silver belonged to whomever discovered them first, and it was usual for a prospector (or a group of associates) to invest 300,000 dirhams on opening a new shaft. Some got rich; some went bankrupt. Working underground with lamps, the miners hollowed out the mountain.[103] According to al-Hamdani some of the people of Andarab worked their own portion of the mine, while others sold their portion to merchants, who worked it (or had it worked). A great amount of silver was excavated each day, the miners spent the earlier part of the day acquiring it, and in the evening it was divided into three parts: one-third for the agent (wakil) of the government, one-third for the miners, and one-third for the people of the place.[104]

There were other silver mines in Khuttal, rich silver mines in Wakhkhan, near Samarqand and Bukhara, in the mountains of al-Buttam, in Farghana, and in the mountains near Ilaq, where there was also a mint for silver coins.[105] The mine of Shash, in the Angren valley, is mentioned by al-Muqaddasi toward the end of the tenth century, when archaeology indicates that silver mining was coming to an end there. So Idrisi may be referring to an earlier period, probably the tenth century, when he describes the great

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[103] Ibn Hawqal, Surat al-Ard, II, 448-9; Lewicki, "Samanides," p. 231; Lowick, "Panjhir mines," pp. 65-6. See also A. Y. al-Hassan and Donald R. Hill, Islamic technology. An illustrated history (Paris, 1986), p. 237.

[104] Dunlop, "Gold and Silver," pp. 40-1; al-Hamdani, al-Jawharatayn, pp. 142-45.

[105] Dunlop, "Gold and Silver," p. 41; al-Hamdani, al-Jawharatayn, pp. 144-5; Ibn Hawqal, Surat al-Ard, II, 445, 475, 476, 488, 505, 509-10; Lewicki, "Samanides," pp. 231-2; Lowick, "Panjhir mines," p. 67.

quantities of silver produced there, where the ore yielded one-quarter pure silver, and how the merchants of Shash bought it and transported it in all directions.[106] Both Lowick and Lewicki argue that the silver dirhams struck by local rulers in Khurasan and Central Asia came from local mines. This makes perfect sense, since these regions are where the mines were, but is most convincing in the case of those dirhams struck at Maʿadin Banjhir and Maʿadin ash-Shash.[107] This might not work so well outside of Khurasan and Central Asia.

At the other end of the geographical spectrum silver mining appears to have revived in North Africa by the eighth century. According to neutron activation analysis the burst of dirham production by ʿAbbasi mints in North Africa in the second half of the eighth century made use of a new source of silver. The mint of Tudgha was near the silver mines of Tamdult, about 40 miles south of Sijilmasa. Silver coins were struck at Tudgha in the name of the ʿAbbasi governors of Ifriqiyya, even though Tudgha was a Sufri Khariji stronghold. The new silver may also have come from the mines at Majjana, between Qayrawan and Tebessa, that are mentioned in the ninth and tenth centuries. Al-Bakri describes Majjana in the eleventh century as a large city with a brick wall, a masjid, several baths, and many mines, including a silver mine that

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[106] Lombard, Les métaux, pp. 43, 238-9.

[107] Lewicki, "Samanides," pp. 224, 231; Lowick, "Panjhir mines," pp. 66-7, 72-3.

belonged to the Luwata Berbers.[108]

Silver mining had revived in Iberia by the seventh century. Slag of lead and copper indicates the exploitation of silver at Cerro de las Minas, south of Guadix, where a Visigothic coin of 672 was found in the slag. This site has several furnaces and seventh- and early eighth-century ceramics.[109] Silver mining continued in the Muslim period in the environs of Córdoba and Sevilla, and in the regions of Almería, Murcia, and Elvira (Granada).[110]

Thus, silver production seems to have peaked in Arabia before the end of the ninth century, while it peaked in Khurasan and Central Asia in the ninth and tenth centuries. At least as much, and probably much more, lead was also produced in the process of extracting silver.

Copper was usually extracted from sulfide ores that needed to be crushed, roasted to burn out the sulfur, smelted with fluxes and partially oxidized.[111] According to Lombard, apart from Cyprus, other ancient sources of copper were no longer active by the late Roman empire. Nevertheless, he asserts that there was

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[108] Ibn Hawqal, Surat al-Ard, I, 84; E. Savage and A. Gordus, "Dirhams for the the Empire," in P. Cressier and M. García-Arenal, eds., Genèse de la ville islamique en al-Andalus et au Maghreb occidental (Madrid, 1998), pp. 377-402.

[109] Bertrand, et al., "Mines et metallurgies medievales," p. 182.

[110] Cosin Corral, "Vascos," p. 108; Cresssier, "Almería," pp. 472, 474.

[111] Al-Hassan and Hill, "Maʿdin," p. 970; G. Weisgerber, "Patterns of Early Islamic Metallurgy in Oman," Proceedings of the Seminar for Arabian Studies, 10 (1980), pp. 116-17. This was basically the same process as in the Greco-Roman world. See Healy, Mining and Metallurgy, pp. 159-60.

Byzantine production of copper in Cyprus, the Taurus mountains, Lebanon, the Sinai, and Upper Egypt from the fifth to the seventh centuries.[112] Copper production seems to have ceased in the Wadi ʿArabah in Jordan at the end of Late Antiquity. Activity at the sites of Khirbet en-Nuhas and Finan (Byzantine Phaino) goes back to the Iron Age, both sites have evidence of Byzantine occupation (Finan was a major town), and both have few Islamic-period sherds.[113] For Lombard the Caucasus, north-eastern Iran, and Central Asia were important centers of copper production during Late Antiquity. But this is based on evidence for the location of copper sources provided by authors writing in the Islamic period, and he assumed "the antiquity of copper-work in these regions."[114] Apparently there is only one known copper mining region in Sasanian Iran around the village of Veshnoveh, about 60 km south of Qum. There chalcocite, bornite, some chalcopyrite, much malachite, and less azurite occur in veins along the top of thick lava flows. The technique was to set fires to loosen the rock, and then to crush the ore with hammerstones either underground or at the pit heads. The presence of a slag dump near the site of Mazrayeh (1.5 km south of Veshnoveh) that derives from the local ore indicates that it was smelted by reduction with charcoal there, although no furnaces have been found. Pottery sherds at Mazrayeh and Laghe Morad (4 km

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[112] Lombard, Les métaux, pp.13-14, 126.

[113] G. D. R. King, "Survey of Byzantine and Islamic Sites in Jordan: Third Preliminary Report (1982), The Wadi ʿArabah (Part 2)," Annual of the Department of Antiquities of Jordan, 33 (1989), pp. 202-3. King notes the presence of Mamluk-period sherds at Finan.

[114] Lombard, Les métaux, p. 37.

southeast of Veshnoveh) indicate that these sites were occupied from the Achaemenian to the Sasanian period, in the early Islamic period, and in the Safavi period.[115]

The early Islamic world was rich in copper with resources from Iberia, North Africa, and Sicily to Cyprus, Iran, and Central Asia. Copper also came from the Caucasus and Ural mountains.[116] Again copper mining in Arabia is overlooked. The mining of copper with silver at Shamam in the Najd and the four ʿAbbasi-period copper mines in the Nukhrah region have been noted above. Musayna'ah, the largest copper mining area in the Nuqrah region, was probably exploited in more than one period. It has shafts and open pits near malachite outcroppings on the upper slopes of hills, and furnace and slag remains indicate that there was smelting near the mines. At Subhah, where malachite and some azurite in quartz were mined, there is copper-smelting slag. An-Nuqrah South has one of the largest copper mines on the Arabian Shield, its exploitation lasted for at least half a century, there is copper-smelting slag scattered in piles to the east of the mine, but no smelting furnaces have been found. There is an open pit mine at an-Nuqrah North, where disseminated copper oxide in weathered chloride ores was mined, although most of the ore was chrysocalla with some malachite. Below twelve meters it may have been copper sulfide. The smelting furnaces at this site have no provision for forced air.

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[115] H. Holzer and M. Momenzadeh, "Ancient Copper Mines in the Veshnoveh Area, Kuhestan-E-Qom, West-Central Iran," Archaeologia Austriaca, 49 (1971), pp. 1-22. This reference was provided by T. J. Wilkinson.

[116] Lombard, Les métaux, pp. 180-87.

De Jesus regards mining as a key industry in the economy of Arabia and suggests that it was a source of wealth for the inhabitants,[117] although this might be exaggerated. Maʿdin an-Nuqrah was also a station on the Darb Zubayda, in addition to being a permanent mining and agricultural settlement, its occupation dated by ninth- and tenth-century pottery.[118] There are four more early Islamic copper-mining sites in the southern Hijaz.[119] Hester notes that small mines would have produced only a few hundred kilos of copper and the largest mines only a few tons, so that the effort would have been worthwhile only if slave labor was used and/or the smelted metal was very valuable. He calls the transport of smelted copper out of the region a "simple, one way, extractive system."[120]

The other main copper-producing region in Arabia was ʿUman, where the mining of copper-bearing pyrites in the Wadi al-Jizzi[121] in antiquity was revived in the sixth century C.E. Charcoal with sixth-century radiocarbon dates from a building and a roasting furnace at ʿArja indicate a resumption of occupation and mining

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[117] de Jesus, "Ancient Mining," pp. 66, 71, 74-6, 78.

[118] N. MacKenzie and S al-Helwah, "Darb Zubayda Architectural Documentation Program. a. Darb Zubayda -- 1979: A Preliminary Report," Atlal, 4 (1980), pp. 37-38.

[119] Hester, "Ancient Mining," p. 123; Zarins, "Central and South Western Provinces," p. 28.

[120] Hester, "Ancient Mining," p. 130.

[121] G. Weisgerber, "Archaeological Evidence of Copper Exploitation at ʿArja," in P. M. Costa and T. J. Wilkinson, The Hinterland of Sohar. Archaeological Surveys and Excavations within the Region of an Omani Seafaring City. The Journal of Oman Studies, 9 (1987), p. 145.

there in the late Sasanian period.[122] The technology was similar to that employed in early Islamic times, which makes it difficult to distinguish late Sasanian from early Islamic workings in ʿUman.[123] The most intensive activity was in the ninth and tenth centuries, when there is evidence of deep mining at al-Bayda', ʿArja, and Lasail. The latter site has inclined shafts as deep as 87.5 meters and horizontal galleries as long as 20 and 30 meters connecting vertical shafts. A narrow gallery with acacia-wood supports roofed with date palm matting was found at Lasail at a depth of 62.25 meters. A bucket handle, parts of a thick rope, and fragments of a windlass found at Lasail at a depth of 87.5 meters indicate the use of machinery for the vertical transport of material. At the surface the ore was sorted and sifted, and large pieces were crushed by hand with hammerstones on large anvil blocks.

The ore was then roasted to burn out the excess sulphur, at the same time converting the iron to oxides and enriching the copper into a sulfidic form suitable for smelting. Since sulphide ores burn by themselves, only a little wood or charcoal was necessary to start the charge burning. More than one roasting stage was usually necessary, and each charge underwent repeated roasting and smelting. Some ores needed more repeated roasting than others. This was apparently the case at al-Bayda', where the

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[122] Costa and Wilkinson, Hinterland of Sohar, pp. 107, 136, 184; Weisgerber, "Archaeological Evidence," pp. 148-9. The copper-ware taken from Sasanian royal treasury in the time of Bahram Chubin (Tabari, Ta'rikh, I, 1057) could have come from ʿUman or Veshnoveh.

[123] Costa and Wilkinson, Hinterland of Sohar, p. 230.

roasting pits occur in groups of three, six, nine or more units, but not at Lasail and al-Sayab, where there are no series of pits.

The roasted ore was then smelted in shaft furnaces with inclined floors. A clay wall in front of the furnace was resealed for each operation. A ceramic tube with a diamater too large for bellows was inserted in the clay wall; air entered by natural draft. The copper matte formed in the bottom of the furnace underneath the slag. The first stage of smelting produced five to six kg of matte (50-60% Cu) and 20.5 kg of slag. The matte was repeatedly roasted and smelted under reducing conditions (with charcoal) until it was transformed into metallic copper.[124] The fuel for roasting and smelting and timbers for the galleries appears to have come from local acacia trees.[125] It has been estimated that between 48,000 and 60,000 tons of copper were produced in ʿUman during the ninth and tenth centuries,[126] although it is unlikely that all of the sites were producing at the same time or continuously throughout this period. Smaller sites would have been worked for a shorter period. Production was at its height in the ninth century, but occupation and smelting at ʿUmani copper-mining sites occured from the sixth until at least the twelfth century C.E.[127] Weisgerber regards the organization of production units for smelting at ʿArja and at al-Bayda' nearby as

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[124] Weisgerber, "Archaeological Evidence," pp. 150-56; idem, "Early Islamic Metallurgy in Oman," pp. 116-17.

[125] Costa and Wilkinson, Hinterland of Sohar, pp. 93, 143.

[126] Weisgerber, "Archaeological Evidence," p. 165.

[127] Ibid., p. 149.

unique in that region. Each unit consisted of roasting installations, one smelting furnace, and one house, suggesting that individual smelters worked independently. There are parallels at other sites outside the Wadi al-Jizzi.[128]

The mining settlement at ʿArja underwent dramatic growth in the early ninth century and lasted until the early eleventh century. There appears to have been a degree of planning at ʿArja, where a compact group of stone buildings is arranged neatly around a rectangular open space overlooking the mine. The ground plans vary from a large courtyard house to elongated agglutinated buildings, some of which are residences. There is also a building complex with rooms for charcoal, sulfur, and water, and ovens for cooking and baking. In addition ʿArja had a masjid and three early Islamic cemeteries. The organization of the settlement led Costa and Wilkinson to compare it to a "company town," although it was not built in a single phase.[129]

Five other early Islamic copper-mining sites in ʿUman have houses clustered in a small village with a masjid and a cemetery. The site at Lasail is much larger than ʿArja but has less evidence of being planned. Blacksmiths' workshops have been found at the copper-working sites of Mullaq and al-Sayab.[130]

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[128] Weisgerber, "Archaeological Evidence," p. 158; idem, "Early Islamic Metallurgy in Oman," p. 118.

[129] Costa and Wilkinson, Hinterland of Sohar, pp. 107-8, 189, 226; Weisgerber, "Early Islamic Metallurgy in Oman," p. 118.

[130] Costa and Wilkinson, Hinterland of Sohar, p. 226; Weisgerber, "Archaeological Evidence," p. 158; idem, "Early Islamic Metallurgy in Oman," pp.118-19.

Nothing is known about the miners, leading to the usual speculation about the employment of slaves or foreigners.[131] But the presence of masjids and Islamic cemeteries indicate that at least some of the miners were Muslim.

Ibadi legal compendia (mainly from the twelfth century) indicate that the mines were owned by people at Suhar, who granted mining concessions to tenants. One could get a license for a limited period of time that had to be fixed exactly and could last up to 100 years. The topographical limits of the mining claim also had to be stipulated. A concession without a time limit was valid for as long as the rent was paid. The rent of a producing mine was about 10% of the net profit, to be delivered to Suhar. In case of conflict the mine belonged to the owner, not to the tenant, and the miners themselves had to be paid by the owner. There were also many mining partnerships (mudaraba) in which both profits and risks were shared, and long-term owner-tenant relationships without written documents or contracts that were considered to be partnerships.[132] One should note here the application of commercial concepts of partnership and contracts to mining production.

But the mining settlement at ʿArja had been partly abandoned in the early eleventh century, and mining had ceased there, although smelting continued through the eleventh and twelfth centuries. By that time the earlier slags were being resmelted, and

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[131] Costa and Wilkinson, Hinterland of Sohar, p. 110; Weisgerber, "Archaeological Evidence," pp. 148, 152.

[132] Weisgerber, "Archaeological Evidence," pp. 147-8.

the technology changed to bowl furnaces dug in the ground for each operation.[133] Weisgerber argues that the mountains of ʿUman were deforested by the need for fuel for smelting, and that it was the lack of fuel that eventually ended intensive copper production there.[134] There is also an eleventh-century copper mining and smelting site in Ra's al-Khaimah.[135]

Elsewhere in the tenth century copper mining is mentioned on Cyprus and at as-Sardan in Fars, whence copper was exported to al-Basra and other places, and in Farghanah.[136] There are eleventh- and twelfth-century references to copper mining in the Kutama mountains of North Africa, whence the copper was sent to Ifriqiyya.[137] Copper was mined in Islamic Iberia in the regions of Elvira (Granada) and Almería, in the Montes de Toledo, and at Rio Tinto.[138] Although Islamic copper mining sites in the Almería region have not been identified, the city of Almería was famous for the copper objects produced there, and the copper mine in Cueva de la Paloma, where the ores are azurite and malachite, appears to be associated with Tijola la Vieja, which has Iberian and Roman sherds, but is first

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[133] Costa and Wilkinson, Hinterland of Sohar, pp. 111, 227; Weisgerber, "Archaeological Evidence," pp. 159-60.

[134] Weisgerber, "Archaeological Evidence," p. 161; idem, "Early Islamic Metallurgy in Oman," p. 119.

[135] N. Lowick and J. Nisbet, "A Hoard of Dirhems from Ra's Al-Khaimah," Numismatic Chronicle, 8 (1968), p. 93.

[136] Ibn Hawqal, Surat al-Ard, I, 300, II, 488; Lombard, Les métaux, p. 180.

[137] Lombard, Les Métaux, p. 82.

[138] Cosin Corral. "Vascos," p. 108.

mentioned in the tenth century as hisn Tajila.[139] Copper or argentiferous galena was probably mined at Los Arrayanes, Jaén province, in the Islamic period.[140]

Iron was important for weapons, armor, gates, and tools. From the fifth to the seventh centuries the Byzantines were provided with iron by mines in northern Anatolia between Sinope and Trebizond, in the Pontus region, and in Lebanon. The latter served the iron industries of Tyre, Damascus, and Bosra.[141] Bosra might also have been served by the iron mine on the southern slope of Ajlan Mountain in Jordan, where there are Byzantine and earlier sherds in the slag deposit, but no evidence of an early Islamic occupation.[142]

It is not entirely true that Muslims began by intensifying the extraction of iron from old mines in the Mediterranean world, as Lombard claims.[143] Not only was iron mining not continued in Jordan, but there was a dramatic increase in iron mining in North Africa in the eighth and ninth centuries. There are several iron mining sites in Tunisia, numerous sites all across northern Algeria, and

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[139] Cressier, "Almería," pp. 473-4, 486-8.

[140] Claude Domergue, Catalogue des mines et des fonderies antiques de la Péninsule Ibérique (Madrid, 1987), I, pp. 288-9

[141] Lombard, Les métaux, pp. 13, 125.

[142] R. Gordon and L. Villiers, "Tulul edh-Dhahab and its Environs Surveys of 1980 and 1982. A Preliminary Report," Annual of the Department of Antiquities of Jordan, 27 (1983), p. 285. This site was exploited in the Ayyubi and Mamluk periods.

[143] Lombard, Les métaux, p. 156.

in the Jabal al-Hadid in north-eastern Morocco from this period.[144] An iron mine at Majjanat al-Maʿdin, between al-Qayrawan and Tebessa, is mentioned in the ninth and tenth centuries and remained a principal mining center until the Hilali invasion in the eleventh century.[145] There was also an iron mine at al-Aribus, west of al-Qayrawan, in the tenth century.[146] Iron mines were exploited near Bône and the mountain above it from the tenth to the fourteenth centuries.[147] An iron mine is also mentioned on Sicily in the tenth century at ʿAyn al-Hadid, near Palermo, that belonged to the ruler and produced iron for the arsenal and the fleet. This mine had belonged to the Banu al-Aghlab, who had taken a great deal out of it,[148] which means that it had been exploited in the latter part of the ninth century.

In Iberia iron mining resumed in the Guadix region in the Visigothic period, peaked there in the ninth century, and then declined through the tenth and eleventh centuries. There are some 30 mining and metallurgical sites in the foothills of the Sierra Nevada south of Guadix. Almost all of them are Visigothic and early Islamic and mainly extracted iron. The Visigothic mining sites tend to be centralized, but there are also many iron work-

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[144] Ibid., p. 159.

[145] Ibid., p. 159; Ibn Hawqal, Surat al-Ard, I, p. 84.

[146] Ibn Hawqal, Surat al-Ard, I, p. 87.

[147] Ibn Hawqal, Surat al-Ard, I, p. 76; Lombard, Les Métaux, p. 160.

[148] Ibn Hawqal, Surat al-Ard, I, 123. The conquest of Sicily by the Banu al-Aghlab began in 827 and was finally completed in 902. But Palermo fell to them in 831, after which mining could have taken place in its vicinity. The dynasty was overthrown in Ifriqiyya by the Fatimis in 910.

shops associated with villas and fundi in the lowlands of the Guadix basin, some 10 to 20 km. from the mines in the foothills. These workshops have furnaces, forges, and slag, and iron agricultural tools, nails, and many iron objects are found on rural sites in the region. Iron production is estimated to have been greater than the needs of the local population.[149]

The main Visigothic mining and metallurgical sites of a concentrated nature in the foothills and the workshops in the valleys were abandoned in the early eighth century, along with a general desertion of the villas and fundi in the center of the Guadix basin. They were replaced by a proliferation of dispersed metallurgical sites in this region, all devoted to iron. Some of the early Islamic sites are on an ancient Iberian metallurgical village (Cerro Cardal) or continue the occupation from the Visigothic period (Cerro Almas, Los Hornillos de Dólar, Castillejo de Ferreira) with their main development in the early Islamic period, but the great majority of them are new foundations. These are characterized by their dispersed nature; innumerable small workshops with furnaces and forges are scattered about these sites, almost always in association with dwellings and a sizeable amount of ceramics. The small amounts of slag indicate that some furnaces were used only a few times. Low production on each site makes the industry seem almost domestic and gives the impression that everyone made their own iron. But the number of workshops indicates that iron production surpassed the needs of the local population. The east-

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[149] Bertrand, et al., "Mines et metallurgies medievales," pp. 181-3.

west orientation of burials in the cemetery at Los Hornillos de Dólar suggests that this population was probably Christian.[150]

Many of these sites were abandoned in about 900, followed by a decline in iron production in the Guadix region in the tenth century, while some sites remained active until about 1100.[151] It has been suggested that the proliferation of iron workshops was connected to Christian (and Muwallad) resistance and the length and violence of disorders in the Elvira region in the late ninth century. The abandonment of refuge fortresses and the metallurgical workshops associated with them by the early tenth century marked the end of that resistance. Afterwards the tenth century saw a shift from mining to irrigated agriculture as the primary economic activity in the Guadix region. Villages and isolated dwellings began to appear in the open countryside or along irrigation canals by the end of the tenth century and especially during the eleventh century.[152]

During the transition some sites continued to be worked. Ceramics associated with the open pit iron mines at Castillejo de Ferreira, south-east of Guadix, date from the fifth or sixth century to about 900; ceramics associated with the furnaces date from the eighth century to about 1100.[153] Sherds associated with the little furnaces of Los Hornillos de Dólar, also south-east of Guadix, date

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[150] Ibid., pp. 183-5.

[151] Ibid., p. 184.

[152] Ibid., p. 188.

[153] Ibid., p. 184.

from the eighth century to about 1100.[154] The size and organization of the concentrated site at Loma Bermite, south-west of Guadix, resembles the large Visigothic mining centers of the sixth and seventh centuries. This site was worked from the late eighth century to the beginning of the twelfth century, which marks the end of iron mining and metallurgical exploitation in the Guadix region[155] until recent times. It is worth noting that the trajectory of iron production from the Visigothic period to the early Islamic period in the Guadix region is remarkably similar to and synchronic with mining in some parts of the eastern Muslim world, where mining built on developments that had already begun.

In spite of a remarkable change in organization in the eighth century, there was no apparent change in the technology of iron exploitation in the Guadix region from the Visigothic to the early Islamic period. In both periods the ores were mainly siderite (iron carbonate), hematite (iron oxide), and goethite (iron hydroxide) with a relatively high iron content (40 - 60%). Ore was usually collected from the surface on the upper parts of mountain ridges, rarely in open trenches following veins of siderite. The primary reduction of the ore, and often the refining, took place where it was extracted or a short distance away in small semi-circular or oval furnaces, 80 cm. to one meter in diameter, backed up against a rock, with the bottom of the hearth generally cut into the rock. The furnace walls were covered with adobe and conical

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[154] Ibid., p. 185.

[155] Ibid., pp. 186, 188.

blast tubes were inserted around the bottom (presumably for bellows). On dispersed sites associated with dwellings the furnaces were scattered about beside the many veins of ore, usually at half-slope or even at the foot of small hills.[156] The city of Vascos, south-east of Toledo and occupied from the ninth to the eleventh century, was also a center of mining and metalwork, where ancient activity was continued in the Islamic period, mainly the extraction of iron and precious metals at La Nava de Ricomalillo. The lack of any change in technology there has been explained by the employment of local labor.[157]

The end of iron mining in the Guadix and Vascos regions after the eleventh century does not mean that iron ceased to be produced elsewhere in Iberia. Iron was produced in the region of Almería in the twelfth and thirteenth centuries,[158] and iron was mined in the mountains north of the Quadalquivir valley in quantities great enough to export.[159]

Iron was also produced in the east. In north-eastern Africa the same sources of iron were exploited in the Islamic period as in antiquity. There was some iron mined in the Libyan desert, the outer Egyptian oases, Nubia, and the Eastern Desert along the Red

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[156] Ibid., pp. 181, 186-7.

[157] Cosin Corral, "Vascos," pp. 107, 118. Islamic mining technology in Iberia is said to be based on the Roman system of vertical shafts, horizontal galleries, drainage, and ventilation (p. 110).

[158] Cressier, "Almería," p. 473.

[159] Arié, Espagne musulmane, p. 248; Lombard, Les métaux, pp. 156-9.

Sea.[160] There was even some iron mining in Arabia, probably as a by-product of other activities. Iron may have been mined at Tawila in the Zulam region in the ᶜAbbasi period, there is some iron slag at Ghuraba in the Ta'if region, that may be pre-ᶜAbbasi,[161] and some iron slag at Rabadha.[162] There is also said to have been an iron mine at Maᶜdin Bani Sulaym, which may be why both the Banu ᶜUsayya and the Banu Farran were called blacksmiths (al-guyun).[163] However al-Hamdani refers to iron mines that were not being worked, such as Nuqum and Ghumdan.[164] There is a much later, thirteenth century, reference to iron mines in the region of Saᶜda, in the Yaman, where the ore was crushed near the mines and then moved to where it was smelted. There were some fifteen furnaces at Rughafah at the entrance to the Wadi al-Jabir mines.[165] There are other, late, twelfth- and fourteenth-century references to the production of iron in the mountain above Beirut, some of which was exported to Egypt, a twelfth-century reference to Cilicia being the richest source of iron, and a thirteenth-century reference to iron mining

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[160] Lombard, Les métaux, pp. 162, 164. Ibn Hawqal (Surat al-Ard, I, 58) mentions iron mined with gold in the region west of the White Nile in the tenth century.

[161] Zarins, "Central and South Western Provinces," p. 28.

[162] Saᶜad bin ᶜAbd al-ᶜAziz al-Rashid, Al-Rabadhah (Riyad, 1986), p. 31.

[163] Lecker, Banu Sulaym, p. 199.

[164] al-Hamdani, Sifat, I, 202.

[165] J. Heiss, "Historical and Social Aspects of Saᶜdah, a Yemeni Town," Proceedings of the Seminar for Arabian Studies, 17 (1987), p. 68; Yaqut, Buldan, II, p. 793.

at Arghana Maʿdin in the region of al-Mawsil.[166] There is no way of knowing whether the sources of iron production mentioned in these later centuries had contributed to the early Islamic economy.

Further north and east the main sources of iron lay in the Caucasus, Armenia, Azerbayjan, Khurasan, Central Asia, Kirman, and Fars. Iron producing centers are identified in southern Armenia in the eighth or ninth century.[167] The iron mines of Jiruft and in the Bariz mountains in Kirman are mentioned in the tenth century, and those of Nayriz and in the hills of Istakhr in Fars in the ninth and tenth centuries.[168] Ibn Hawqal, in the tenth century, mentions many iron mines near Kabul and says that the sources of iron in Central Asia exceeded the demands of commerce, while Idrisi, in the twelfth century, notes the excellent iron produced by the mines near Kabul.[169] The Helmand basin and the upper Hari-Rud were famous for their sources of iron in the tenth and eleventh centuries.[170] Iron is also noted as coming from the mountains of Central Asia in the tenth century.[171] Lombard considers Armenia and Azerbayjan to have been the most important for iron production

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[166] Lombard, Les métaux, pp. 165-66.

[167] Ibid., p. 167, by Pseudo-Moses of Khoren.

[168] Ibn Hawqal, Surat al-Ard, I, 300, II, 310; Lombard, Les Métaux, p. 173.

[169] Ibn Hawqal, Surat al-Ard, II, 450, 464; Lombard, Les Métaux, p. 172.

[170] Lombard, Les Métaux, p. 172.

[171] Ibn Hawqal, Surat al-Ard, II, 488; Lombard, Les métaux, pp. 171-2.

because of the presence of forests for fuel,[172] but al-Hamdani mentions an iron mine at Tus, in Khurasan, in the tenth century, from which coats of mail were made.[173]

Lead was produced in most places that silver was, but was also mined separately.[174] The latter led Ashtor to argue that the supply of lead in the pre-modern Islamic world was probably not sufficient for its uses, and that it was probably imported,[175] overlooking the large amounts of lead that were a by-product of silver mining. It was more likely the other way around. Uses were found for the lead that was left over from silver mining, and, according to Lombard, lead was used massively in the early Islamic world: for water conduits, baths, roofing, glazing pottery, crystal, sealing, perfume containers, and coins.[176] The second problem with Ashtor's argument is that it treats the Islamic world as a unitary economy with religio-political boundaries. It is not at all certain that the borders between Muslim and non-Muslim territories were any more significant than those between localities and regions within the Islamic world in terms of economic exchange.

Apart from those centers of silver mining noted above, where

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[172] Ibid., pp. 166-73. On page 154 he estimates that 40 to 50 tons of charcoal would be needed to produce one ton of iron.

[173] Dunlop, "Gold and Silver," p. 41; al-Hamdani, al-Jawharatayn, pp. 144-5.

[174] For the sources of lead in the early Islamic world see Lombard, Les métaux, pp. 189-91.

[175] E. Ashtor, "Maʿdin," EI(2), V, p. 964. It is true that Ibn Hawqal reports that the Arthaniya Russians exported lead and some mercury, presumably to Islamic territory (Surat al-Ard, II, 397).

[176] Lombard, Les métaux, p. 192.

lead would also have been produced from the galena ore, we also hear of a lead and silver mine at a place called Tutis in the northern Jazira, in Fourth Armenia, in 773-4. It is said that, because of contemporary economic hardship, many people from all regions gathered where the lead was produced, forming a large camp with an agent appointed by the ruler, and dug wide and deep tunnels searching for lead.[177] Ibn Hawqal notes a lead mine at a village near the citadel of Katha in Yazd in the tenth century.[178] The galena mine at Solana de Ballesteros, in the province of Cuidad Real, in Iberia, that was active in the tenth and eleventh centuries, produced 3,200 kg of silver to one ton of lead. It went down 70 meters and had galleries.[179]

In addition to gold, silver, copper, iron, and lead, mining in the Islamic period included the extraction of mercury, zinc, tin, precious and semi-precious gems (emeralds, topaz, lapis-lazuli), ochres, natron, sal ammoniac, alum, and salt. Coral and pearls were also taken from the sea. In some places there was a combination of mineral resources. Gold, silver, copper, iron, and steatite (see below) were mined in western Arabia. Armenia was a source of silver, iron, copper, lead, borax, arsenic, mercury, and salt.[180] According to Ibn Hawqal tenth-century Fars was self-sufficient in minerals without the need to import them, except that

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[177] Amir Harrak, The chronicle of Zugnin, Parts III and IV, A.D. 488-775 (Toronto, 1999), p. 300.

[178] Ibn Hawqal, Surat al-Ard, II, 280.

[179] Domergue, Catalogue des mines, I, pp. 74-5.

[180] Hovannisian, Armenian People, p. 183.

there was little silver. He notes the presence of mines of silver, iron, lead, sulfur, naphtha, gold, copper, and mercury in Fars.[181] There was more than one mine of copper, iron, silver, turquoise, hematite, and malachite in the mountain of Nuqan between Nishapur and Tus.[182] Farghanah had mines of gold, silver, mercury, bitumen, asbestos, turquoise, iron, copper, and lead, plus resources of rock crystal and sal ammoniac.[183] Mineral-rich Iberia probably produced the most complete list: gold, silver, copper, lead, iron, mercury, zinc, antimony, tin, alum, salt, coral, rubies and other gems, lapis-lazuli, and white marble.[184]

Mining production was substantial and economically important rather early in Muslim Iberia. In 758 ʿAbd ar-Rahman I is said to have fined the Christians of Qastilya, in the province of Elvira, 10,000 ounces of gold, 10,000 pounds of silver, over 10,000 coats of armor, and 1,000 iron helmets annually for five years. Clearly this province not only had resources of gold, silver, and iron, but these were available to (and probably produced by) the native population. Under al-Hakam I and ʿAbd ar-Rahman II (796-852) the annual income to the government from mines in the province of Elvira alone

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[181] Ibn Hawqal, Surat al-Ard, II 300.

[182] Ibid., p. 434.

[183] Ibid., pp. 488, 515.

[184] Arié, Espagne musulmane, pp. 248-9; Constable, Trade and Traders, pp. 185-7; Cosin Corral, "Vascos," pp. 108; Cressier, "Almería," pp. 473-4; Ibn Hawqal, Surat al-Ard, p. 114.

amounted to 42,000 dinars.[185] It has also been noted that there is a pattern of fortified sites (either for control or protection) associated with Berber settlements and mining and metallurgy in the Middle March.[186] Iberia should probably not be treated as a single economic region.

Quarrying was also important in early Islamic Arabia. Large, circular grindstones are fairly common at mining sites in Arabia, and it is usually assumed that they were used to crush the ore. That they were more likely to have been used to grind grain for the miners has been noted already.[187] Nevertheless, Kisnawi is probably right to regard the quarrying of grindstones as an important sub-industry of mining (as also of agriculture), and he identifies two Islamic-period quarries in the northern Hijaz, one for vesicular basalt and one for pink granite.[188] Massive steatite talc was also mined and carved into incense-burners and cooking utensils in ancient Arabia, with no apparant reduction in production until after the ᶜAbbasi period. There are impressive ᶜAbbasi-period

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[185] Bertrand, et al., "Mines et metallurgies medievales," pp. 187-8. The information about the fine on the Christians of Elvira occurs in a document of security (kitab aman) quoted by the fourteenth-century historian, Ibn al-Khatib. The information about the mines of Elvira comes from al-Udhri (1003-85). A. Carbonell, "La minería y la metalurgia entre los musulmanes en España," Boletín de la Real Academia de Ciencias de Córdoba, 25 (1929), pp. 179-217 identifies most of the mines in Muslim Iberia, especially those around Córdoba during the Umawi caliphate.

[186] Grañeda Miñón, et al., "La minería medieval," pp. 252-3. Xenophon had advocated fortresses as a place of refuge for miners in case of attack (Healy, Mining and Metallurgy, p. 112).

[187] See page 00 above.

[188] Kisnawi, "Mining Survey," p. 79.

steatite mining sites at Wadakh, in the Dawadami region, at Ghuraba, in the Ta'if region, and at Umm Lajj, in the northern Hijaz, that have the remains of carved steatite objects in all stages of preparation.[189]

The most obvious difference from Late Antiquity is the sheer extent of mining in the early Islamic economy. Minerals, of course, had to be exploited where they were located, and, in the preceding discussion of different metals, certain key regions recur. The centers of mining production lay in the Caucasus, Armenia, northern Iran, Fars, Central Asia, the Najd, Hijaz, Yaman, and ʿUman in Arabia, the Sofala region in East Africa, the upper Nile region, the central Maghrib, Ghana in West Africa, and Iberia. Other regions are conspicuous by their absence. There is no evidence of early Islamic mining in Cyrenaica, Lower Egypt, greater Syria (with evidence that mining was abandoned in Jordan), Mesopotamia, eastern Arabia, and much of central Iran. Ibn Hawqal says that there was not a single mine of gold or silver in the entire Jibal,[190] and that there were no mines of gold, silver, or precious gems in Khwarazm.[191] Of course, in some places, such as the Nile delta, lower Mesopotamia, and the Oxus delta there were no metals to be mined.

The expansion of mining appears to have begun in about 600 C.E., and the peak of production occured during the ninth and tenth centuries in most places. This impression is based on a combina-

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[189] Kisnawi, "Mining Survey," p. 79; Zarins, "Central and South-Western Provinces," p. 28.

[190] Ibn Hawqal, Surat al-Ard, II, 373.

[191] Ibid., p. 481.

tion of archaeological reports and literary references. Usually the dates of mining sites have been determined by the pottery found there, which can only give an approximate date, is subject to revision, and contains the assumption that the pottery found on a site was that used by the miners or at the same time that the mine was worked. The literary references mainly come from Arabic-writing authors of the ninth and tenth centuries (especially geographers). Naturally this creates the impression that this was when most of the activity occured, although their information is commonly retrojected onto earlier periods in modern scholarship. The picture might be different if there had been an eighth-century geographer.

But the difference with Late Antiquity was not merely in the extent of mining and the amount of production. It was also in the technology (except in Iberia).[192] Previously unexploitable ores were mined, shafts tapped subsurface deposits, and these ores were processed by a wider application of mercury amalgamation, cupellation, and cementation. This was a technology that was, if anything, more labor and energy intensive than before. Smelting often occured near the mines, even in places where fuel seems to have been less available, such as western Arabia. It was clearly in someone's

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[192] Muslim mining technology in Iberia was based on the Roman system of vertical shafts and horizontal galleries, Archimedean screws (first used in Iberian mines in the early first century C.E.) and waterwheels (used by the Romans at Rio Tinto) to drain the shafts and galleries, and pulleys to raise the ore (Cosin Corral, "Vascos," p. 110; Healy, Mining and Metallurgy, pp. 94-5, 98-100, 102). There is a Roman cupellation furnace at Castuera, Badajoz province, where galena was mined (Domergue, Catalogue des mines, I, p. 28).

interest to go to all this trouble.

It is possible to extract a typology of exploitation by individual miners, merchants, and government agents from scattered literary references. But these were almost always mixed at any particular mine. There were both individual local miners and merchants at Panjhir and Wadi al-ʿAllaqi; in Yaman the government and the people divided the new gold mine at Dankan, while the ruler's agents and independent miners exploited ar-Radrad. An iron mine on Sicily was owned by the ruler, while under the Fatimis government agents ran Wadi al-ʿAllaqi. There was also private ownership of mines at Panjhir, where a new vein of silver belonged to whomever found it, and in ʿUman, where the owners of mines leased them. Investment seems to have come from all three types. Compared to Late Antiquity, when mines were leased from the government in Armenia, there appears to have been relatively more involvement by independent miners and by merchants in the Islamic period.

Another difference with Late Antiquity was in the nature of the labor force. Slave labor does not seem to have been available for mining in Late Antiquity, but the requirement of miners to be bound hereditarily to that occupation was in some sense forced labor. There appear to be only two examples of slave labor in early Islamic mining: at Wadi al-ʿAllaqi and in the Yamama. Otherwise the labor force in early Islamic mining seems to have been relatively free and mobile. The houses at mining sites in Arabia suggest that there were different forms of organizing labor. These vary from rows of one-room structures or one- to three-room houses

in western Arabia to the one-house smelting units at Arja or houses clustered in villages at other sites in ʿUman. At this point one can only speculate about what these differences might mean, and, for the rest, we are left with the mute testimony of the mines themselves.