

Siphnos, in the Laurion district of Attica, on Thasos, and in Thrace. Their success was reflected in the prosperity of Siphnos in the sixth century B.C. and of Athens in the fifth century; their failure, in their subsequent decline.

Copper was mined near Chalcis on Euboea and in quantity on Cyprus. Trace elements perhaps accounted for early alloys (arsenical bronzes), but large-scale production of bronze depended on imported tin (from Asia, Spain, Gaul, and Cornwall). Greeks mined iron locally, obtaining more from Elba and Asia Minor. Italy was not rich in ores, but Etruscans and others mined some gold, copper, and iron, notably on Elba. Rome's expansion gave her control of rich mines of gold, silver, and base metals in Spain and in other provinces, including Britain (gold, lead, and iron). Lead and zinc, neglected by Greeks, were mined extensively by Romans.

Ancient miners used, at need, placer mining of river and alluvial deposits, open-cast workings for ores close to the surface, adits and galleries, sloping or horizontal, for ores farther in, and vertical pits with gallery extensions for deeper lodes. Prospectors often located mineral deposits from the discoloration of surface rocks, such as the rusty or dark staining caused by iron and manganese trace elements. Oxide and carbonate ores were mined nearer the surface, sulphides deeper down. Miners followed veins of ore, hollowing out pits or underground chambers where the lode was rich, economizing on labor and pit props elsewhere by cutting low (3 feet [1 m] or less), narrow galleries of rectangular or trapezoidal section. Hand tools, earlier of stone or bone, later of iron, included spiked hammers, mauls, chisels, single- and double-pointed picks, mattocks, shovels, rakes, baskets and leather bags for carrying ore, ropes, ladders, buckets, and windlasses for hauling it up pit shafts. Ore was selected at the workface and again at the surface, waste being packed into abandoned chambers or dumped outside. Miners exploited both fire and water: they lit fires and quenched them with water (or vinegar) to split rock (fire-setting). Elsewhere they directed water from streams and reservoirs to remove surface cover (hushing). They faced problems of light, ventilation, heat, and drainage. Torches and oil lamps provided a smoky light. Air circulation was improved by using cloth fans, twin shafts, parallel galleries, and ventilation shafts, often with fires lit to create up-and-down drafts. To improve drainage the Romans used channels, baling, Archimedean screws, and waterwheels (preserved fragments found at Rio Tinto, Spain, and Dolaucothi, Wales). Even so, conditions were generally appalling, and Greeks used slaves for both underground and surface operations. The Romans made use also of criminals, forced labor, and sometimes soldiers, keeping some workers permanently underground. Technicians and overseers too were often slaves.

Mining rights were usually a state monopoly, but exploitation was mostly indirect. Athens leased concessions at Laurion to citizens for fixed terms; surface works were built, operated, and sold by individuals. In Ptolemaic Egypt, mines were state-owned and state-run. In Republican Rome, mines were leased to contractors (*conductores*) and companies (*publicani*); under the Principate there was stricter control through imperial procurators.

Science and archaeology have supplemented the evidence of ancient authors and inscriptions (such as Athenian mine leases and Roman mine regulations from Portugal). Lead-isotope analysis has distinguished the characteristics of argentiferous lead ores from Siphnos and Laurion and

silver artifacts made from them. Exploration on Siphnos has revealed silver mining there in the Early Bronze Age (third millennium B.C.) and the deliberate refilling of galleries and shafts with rubble, perhaps for religious reasons. In Attica, silver mining at Thorikos has been dated back to the same early period, and elsewhere in the Laurium area, excavation has uncovered many adjuncts of the mines of the Classical period: rainwater reservoirs for ore-treatment, grinders with blocks and handmills for ore-crushing, cemented washing tables for concentrating ore and recycling precious water, workshops, slave "barracks," and smelting furnaces.

■ Oliver Davies, *Roman Mines in Europe* (1935). R. J. Forbes, *Studies in Ancient Technology*, Vols. VII, VIII-IX (1963, 1964). John F. Healy, *Mining and Metallurgy in the Greek and Roman World* (1978). Constantin E. Conophasos, *Le Laurium antique* (1980). Robert Shepherd, *Ancient Mining* (1993).

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AUSTRALIAN MINES

Throughout Australia raw material for the manufacture of stone artifacts was often procured simply by collecting rock from creek beds, gibber plains, or rock outcrops. Approximately two-thirds of recorded quarries show no signs of prehistoric digging, and procurement was limited to exploitation of naturally fractured rubble mantling the ground surface. This surficial exploitation is typical of the numerous silcrete, quartzite, and chert quarries. Artifact manufacture at these quarries generally produced a range of retouched and unretouched flakes. Such sites have proved difficult to date, although there are indications of antiquity. At Northcliffe in western Australia, for example, silcrete was obtained during the Early to Middle Holocene.

More spectacular are the quarries where rock has been dug from the ground. Archaeological manifestations of the excavations are either semicircular depressions that indicate the position of pits dug to obtain subsurface rock, or trenches that indicate excavation along a seam of rock. The oldest securely dated stone quarry is Koonalda Cave, where flint was extracted more than 20,000 years ago. Many of these excavated quarries were used to produce artifacts for exchange. Ground-edge axes were manufactured at other excavated quarries and traded widely. Important quarries for trade-related axe production include Mount William in Victoria, Lake Moondarra Quarry 1 in northwest Queensland, and the Moore Creek Quarry in New South Wales. The antiquity of these axe quarries is attested only at the Bendemeer I rock shelter, where an axe from Moore Creek was dated to more than 1300 B.P. However, the presence of axes in northern Australia during the Pleistocene may indicate that similar quarries have far greater antiquity. Other quarries, such as Ngilipitji in the Northern Territory, produced large quartzite flakes for recent exchange systems.

True mines, forming artificial subterranean passages, are rare in Australia. Horizontal shafts are known only from other mines. At such sites, tunnels were dug into seams of high-quality ocher, often with the use of stone or wooden wedges and stone hammers. Evidence for wooden scaffolding has also been found. The best known ocher mines are Wilgie Mia in western Australia and Campbell Ranges in the Northern Territory. At Wilgie Mia, a large open-cut pit terminates in a series of tunnels that follow seams of red and yellow ocher. Radiocarbon dates indicate that mining at Wilgie Mia has occurred for more than 1,000 years, and in 1952 D. S. Davidson estimated an antiquity of several thousand years based on the volume of rock extracted. Indica-

tions of age are also available for the other mine in the Campbell Ranges, where 300 tons of red ochre have been removed. Historic and modern extraction at this site averaged 110–132 pounds (50–60 kg) per annum, permitting an estimate of 5,000 to 6,000 years for mining activities at the site.

While ochre mines are renowned, much ochre was obtained by open-cut quarrying. Ochre quarries are found in all regions of Australia, but are dated only in Tasmania, where a radiocarbon date at Gog Range suggests an antiquity of 400 years. Since red ochre has been used in rock art and burial rituals for at least 20,000 to 30,000 years, ochre mining and quarrying may have a similar antiquity. Ochre was highly prized for decorative purposes, and was traded widely.

In the recent past access to major quarries central to trade networks was restricted. Restrictions came in a range of forms, and quarrying was not limited to males. For example, quarrying at the Mount William Quarry was the prerogative of a single man. At the Campbell Range site, access to ochre was controlled by an extended family, and ochre was mined by both males and females. Axe quarries near Lake Moondarra Quarry were worked by many members of the Kalkadoon group, and W. E. Roth reports a sexual division of labor, with males undertaking initial mining and females the final grinding.

■ W. E. Roth, "Domestic Implements, Arts and Manufactures," *North Queensland Ethnography Bulletin* 7 (1904). D. F. Thomson, *Economic Structure and the Ceremonial Exchange Cycle in Arnhem Land* (1949). D. S. Davidson, "Notes on the Pictographs and Petroglyphs of Western Australia and a Discussion of Their Affinities with Appearances Elsewhere on the Continent," *Proceedings of the American Philosophical Society* 96 (1952): 76–117. R.V.S. Wright, *Archaeology of the Gallus Site, Koonalda Cave* (1971). N. Peterson and R. Lampert, "A Central Australian Ochre Mine," *Records of the South Australian Museum* 37 (1985): 1–9. P. Hiscock and S. Mitchell, *Stone Artifact Quarries and Reduction Sites in Australia: Towards a Type Profile* (1993). Peter Hiscock

MISSION ARCHAEOLOGY is a complex undertaking that amounts to no less than studying a microcosm of the colonial experience itself. Missions were among the most powerful institutions of the Spanish Crown for converting and "civilizing" the native populations, commandeering labor and provisions, and establishing a presence in the vast frontier territories of Spanish America. Friars were often the first representatives of European culture to interact with Native American groups, and their contact was frequently sustained over a considerable period of time. Consequently, the study of these unique settlements stands to make valuable contributions to our understanding of acculturation processes and to contact period studies as a whole. Mission archaeology also underscores the unique advantages of *historical archaeology, since Spaniards were fastidious in keeping both religious and civil records of events at many of the missions. Bearing in mind that they usually represent only the Spanish perspective, these documents provide an invaluable backdrop against which mission archaeologists can develop hypotheses and evaluate their findings.

The earliest Spanish mission efforts in North America began in the sixteenth century; however, their florescence did not occur until the seventeenth and eighteenth centuries. Missions were concentrated in an area referred to by researchers as the Spanish Borderlands—a broad, roughly defined territory along the northern rim of New Spain. The Spanish Borderlands encompass parts of Mexico and the

present-day southern United States from Florida to California. Most people immediately associate Spanish missions almost exclusively with California and the Southwest, since the mission buildings were constructed of permanent materials and are often still marked by standing ruins. More importantly, many of the southwestern native populations have living descendants who keep their ancestors' cultural heritage alive. By contrast, there are no visible remains of any missions in the Southeast, and none of the indigenous tribes who occupied the missions of Spanish Florida survived as a people (the Seminole and Miccosukee Indians associated with Florida today are eighteenth-century immigrants). As a consequence, mission researchers in the Southeast are facing distinctive challenges. Not only must the mission settlements themselves be found through archaeological techniques, but the direct historical approach to understanding the native cultures is not an option. Therefore, while all mission archaeologists are examining cultures in transition, southeastern mission archaeologists are documenting the final episode in the lives of the early native inhabitants of Spanish Florida prior to their virtual annihilation.

In large part due to the high visibility of the ruins, mission archaeology began in the American Southwest and California long before any attempts were made at studying the missions of Spanish Florida. While there were numerous mission excavations conducted during the first half of the twentieth century in the western borderlands, full-time efforts at mission archaeology were not undertaken in the Southeast until the 1970s. As a result, data from various missions throughout the Spanish Borderlands are not always comparable, since research goals, field methods, and data bases (particularly remains necessary for environmental and subsistence studies) have changed dramatically over the decades.

Archaeologists have found that Spanish missions were as varied as the natural and cultural landscapes on which they were imposed. In parts of northern Mexico, Texas, and California, where the native populations were dispersed and semisedentary, missionization called for dramatic changes in indigenous settlement patterns and seasonal rounds. Since living in permanent communities was an essential element of being civilized by European standards, friars removed natives from their traditional house sites and forced them to live in mission compounds (*reducciones*) year-round. Archaeologists in California frequently identify the remains of Indian barracks or dormitories associated with mission complexes (for example, La Purisima Concepción among the Chumash and Mission San Antonio among the Salinans). By contrast, many of the missionaries who worked among sedentary farming societies, such as the Pueblo Indians of New Mexico and the natives of Spanish Florida, were able to establish missions at extant major villages and impose their authority through the conversion of chiefs and other tribal leaders.

Despite the fact that natives provided the labor responsible for constructing the European-style buildings at missions (including church complexes, residences, and even military fortifications), exposure to Spanish building designs, techniques, and hardware appear to have had little influence on indigenous architectural traditions. One of the best examples of this phenomenon is found at Mission San Luis de Talimali, in present-day Tallahassee, Florida. The site had no premission occupation but rather was selected by the Spaniards for its strategic location. Subsequently, a