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THE PRODUCTION OF ROMAN RURAL IRONWORKERS IN THE NORTHEAST OF HISPANIA TARRACONENSIS.

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SUMMARY

One of the most populated and romanized zones of the ancient times was the northeast of the Iberian peninsula (*Hispania Tarraconensis*). In this area there was a proliferation of Roman rural developments (*villae rusticae*) devoted to the production and marketing of high-price agricultural products for which there was a great demand. In this context of autonomous rural units of production and consumption, the craft trades, and in particular metalworking, emerged and began an atypical exploitation and capitalization of the natural resources of rural property (*fundus*), either for their own consumption or to satisfy a local demand.

The analysis of micrographic structures of nails has allowed us to ascertain that the Roman rural ironworkers of the early empire (1st to 3rd centuries AD) knew and practiced most forging techniques. They used both heat treatment (carburation, quenching, etc.) and mechanical treatment (lamination by forging, bending, etc.), but the quality of the technical processes shows that, though specialized, the workers were not highly qualified. Furthermore, the standardization of the technical processes and the homogeneous nature of the final product suggest that the rural ironworker was more a workman applying acquired techniques and practices than a craftsman providing different solutions to specific problems.

The importance of the knowledge of iron equipment manufacture lies in the fact that the agricultural model of some economically active areas of the Roman empire required technological products and found it feasible to integrate their manufacture as a complementary activity on a farm.

INTRODUCTION

The least known aspect of Roman rural metalwork in the Iberian peninsula is the manufacture of iron objects. Until the present, the problem of infrastructures, the working method and the technological skills of the Hispanic Roman rural ironworker had not been approached. These factors are all related to the dimensions and orientation of the activity and to the social and legal status of the craftsman. The recent identification of some forges in the *villae* of El Vilarenc (Calafell, Tarragona) and the area of Iluro (Mataró, Barcelona), and the analysis of their products together with those of the *villa* of Vilauba (Camós, Gerona), dating from between the middle of the 1st century AD and second half of the 3rd century AD, allow us to consider these problems (Fig.1). The importance of the knowledge of iron equipment manufacture lies in the fact that the agricultural model of some economically active areas of the Roman empire required technological products and found it feasible to integrate their manufacture as a complementary activity on a farm.

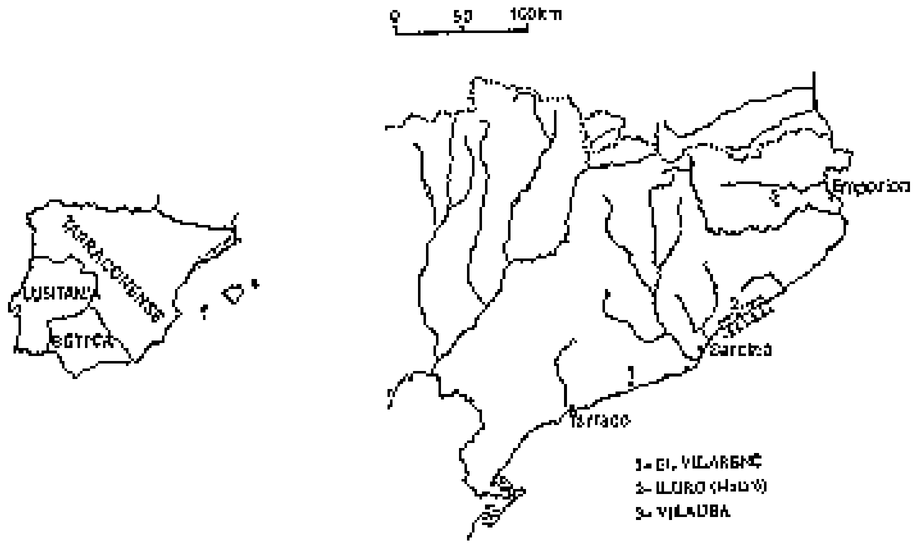


Fig. 1. Location of the *villae* and the mentioned areas.

THE RURAL IRONWORKER IN THE COASTAL REGION OF HISPANIA TARRACONENSIS

The coastal region of the northeast of *Hispania Tarraconensis* was one of the most romanized and densely populated zones of Roman *Hispania*. In this area, near to important cities such as Tarraco, Barcino and Emporion there emerged smaller ones such as Iluro. In the *hinterland* of all these towns the occupation model and development of the territory based on the system of *villae rusticae* took place from the end of the Republic and during the High Empire. The *villae* were rural developments devoted to the production and marketing of high-price agricultural products, for which there was a great demand. In this context, the rural craft trades (pottery and metalwork) emerged and began an atypical exploitation and capitalization of the natural resources or the geographical location of the rural property (*fundus*). Their products were for their own consumption and to satisfy local demand, which found it more economical to acquire the products or services of a given specialist than to maintain him as a producer in the *fundus* (1).

The forges located in Roman sites (*El Vilarenc*) have a raised construction (2), and are clearly different from the traditional Iberian forges dug out of the earth. Their spatial arrangement suggests that rural metalwork shops in *Hispania Tarraconensis* were of modest dimensions and needed only a small number of workers: an ironworker, helped by an assistant or apprentice, whose primary activity was manufacturing and repairing agricultural tools and equipment, in addition to occasionally handling other functionally useful metals (bronze and lead). Nevertheless, some workshops, such as those of El Vilarenc, developed the whole manufacturing chain (obtaining, processing and manufacturing) of iron; the same happened in Gallia (3) and Britannia (4).

It is difficult to establish the social and legal status of iron workers by reference to the metallurgy in Latin literature, since like all of the rural population they were anonymous. In the Roman world, regardless of their legal status (slave, freedman or freeborn) neither urban nor rural ironworkers had much social consideration (5). The collective need for a given activity and the degree of apprenticeship needed to learn it did not themselves confer social status on the practitioners. The lack of prestige of manual work in Greek-Latin society, as opposed to Celto-Germanic society, affected all crafts equally, including the pyrotechnological ones. The rural ironworker, as a *faber rusticus*, occupied a position only slightly above that of the peasant (Pliny, N.H., *praef*. 6). This was because he was a manual worker (*opifex*) who had to sell his labor to survive, and a rural worker (*rusticus*) who was outside the urban environment, and therefore removed from guilds and civic life (6).

Nor does the archaeological evidence of metal workshops allow us to reconstruct clearly the forms of management of the rural forges. To gain an idea of the management of the forges and the status of the ironworker, we have to appeal to parallelism in other kinds of rural craft trades (7) that were complementary to agriculture, of which we do have references: ceramic production, which could be organized separately from the principal economic activity, regardless of its final integration in the agricultural cycle (8).

Regardless of the personal status, were these people craftsmen or qualified workmen? We are inclined to consider them as simple workmen, because a predetermined or standardized demand (with no artistic pretensions), and the need for repair, minimized the personal initiative of the ironworker, who merely manufactured equipment repetitively. The relative complexity of the infrastructures and less than optimum quality of the various technical processes also shows work that did not require a high degree of specialization and that could even be separated from other tasks. The rate and volume of production, limited strictly by the internal need of the *villa*, should be valued in the same sense. However, the analysis of microstructures in the zones studied shows the existence of some general knowledge that we could call "technological culture", acquired and practiced by the metal workers of the *villae*.

STUDY OF IRON

Since the most numerous iron materials from Roman sites are nails, we began to study them in order to find metallic structures that allowed us to determine the kind of iron used and the technological skills that had been acquired.

Methodology

In the first phase we chose nails with both a head and tip. We cut both ends and prepared the surfaces of the cross-sections for observation and analysis. The state of conservation of the nails is very poor. Under a surface crust almost all of them are mineralized. Upon conducting cross-sections to the ends of the nails, we saw that most of them were hollow. This, which at first surprised us, made us think that they would be worthy of study.

25 nails were selected (17 from El Vilarenc and 8 from Vilauba), and it was attempted to use a sample of all kinds: whole and fragmented, straight and twisted. They were 4.5 to 10 cm. long, with a tiller width of 1 to 2.5 cm.

Instead of cross-sections, we obtained longitudinal sections using two alternate methods: making parallel cuts until the longitudinal central axis was reached, or grinding the nail in successive planes until the longitudinal central axis was reached. This technique gave us a progressive and continual view, and allowed us to pay attention to the appearance of metallic patches. All the surfaces of the longitudinal central section of the nails showed the existence of two structures parallel to their longitudinal shaft, which were normally separate leaving a central hollow running from end to end. On the outer surface of the nails we often observed charcoal incrustations, which were also observed in some zones of the walls of the central hollow. The longitudinal central hollow disappears due to the joining of the internal walls before the distal end of the nail. The edges of the walls of the two sides are sometimes joined at some point along the nail.

For the observation of the structures, an optical microscope (ZEISS Photomicroscope) and a scanning electron microscope (JEOL 6400) were used. The method of analysis by x-ray energy dispersion (LINK-XL5) was used to obtain the quantitative elemental composition of the different phases.

Results of the study of the micrographic structures

In most of the nails no metallic structure remains, apart from some isolated particles. A continuous metallic structure was found only in two nails, one from El Vilarenc and one from Vilauba.

In the observation of the nail section surfaces in the microscope, remains of pearlitic structures appear: that is to say, the iron carbide Fe_3C (cementite) is present while the α-iron (ferrite) is in the oxidized state (Fig.2). These remains are found in a greater quantity in the zones near the center of the nail. Sometimes, the plates of cementite were removed during the polishing or cutting, due to their greater hardness, and only the imprint remains (Fig.3).

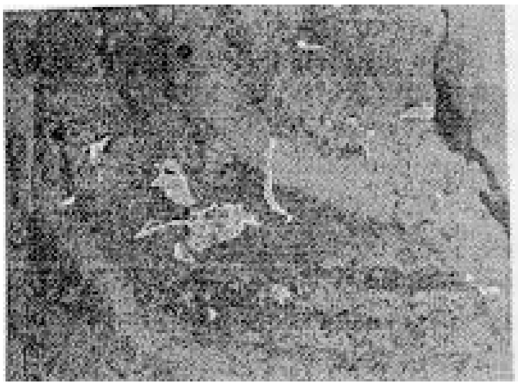
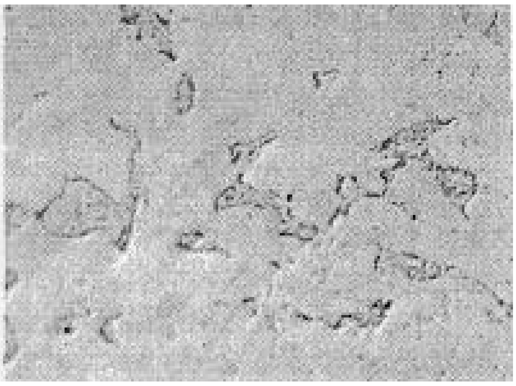



Fig. 2. Laminiform cementite of the pearlite in a matrix mineralizated.
Fig. 3. Imprint of the cementite of the pearlite in a matrix mineralizated.

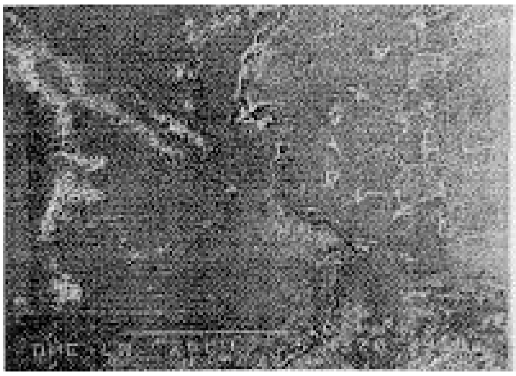
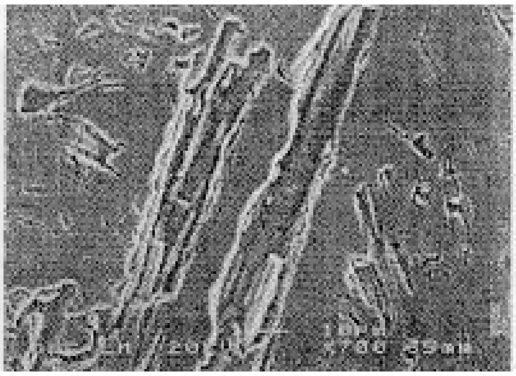



Fig. 4. Of the right, metallic structure which consists of ferritic grains (grey) and intergranular pearlite (white). Of the left, mineralizated structure with laminated cementite and imprint of the cementite.
Fig. 5. Pieces of charcoal in the hearth of a nail.

Where sufficiently large metallic areas remain, a structure formed largely by ferrite can be observed, with pearlitic grains of a smaller size at the edges of ferritic grain. It is therefore an Fe-C alloy, which is poor in carbon. Surrounding the metal, mineralized material can be found with different degrees of oxidation, in which there remain either the cementite chains of the pearlite, or the imprints left by removal (Fig.4).

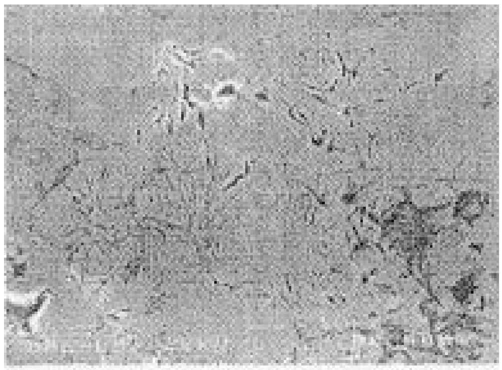


Fig. 6. Martensite imprint in a mineralizated matrix of the nail surface.

As we have said, charcoal fagots are observed on the external face of the nails, sometimes covered with iron oxide that had been presumably in a metallic state. But charcoal is also found in the internal central wall of the hollow (Fig.5).

Just as remains of cementite belonging to the pearlite grains are found in the oxidized structure of the nails, on the outer face of one specimen the trace of a structure that could be martensite is observed (Fig.6).

Results of the analysis by X-ray energy dispersion

All the analyses were repeated in different zones of a sample (nail) and in different samples. Here only a few representative examples are mentioned.

At first sight, the external oxidation layer seems to be filled with incrustations. The elements that appear in the analysis are: Si, Al, Ca, K, Mg, Fe, O. The mappings in Fig.7 show the distribution of the majority elements: oxygen (Fig.7-2), iron (Fig.7-3), calcium (Fig.7-4) and silicon (Fig.7-5) from the external edge to the internal edge of the central section of the mineralized nail.

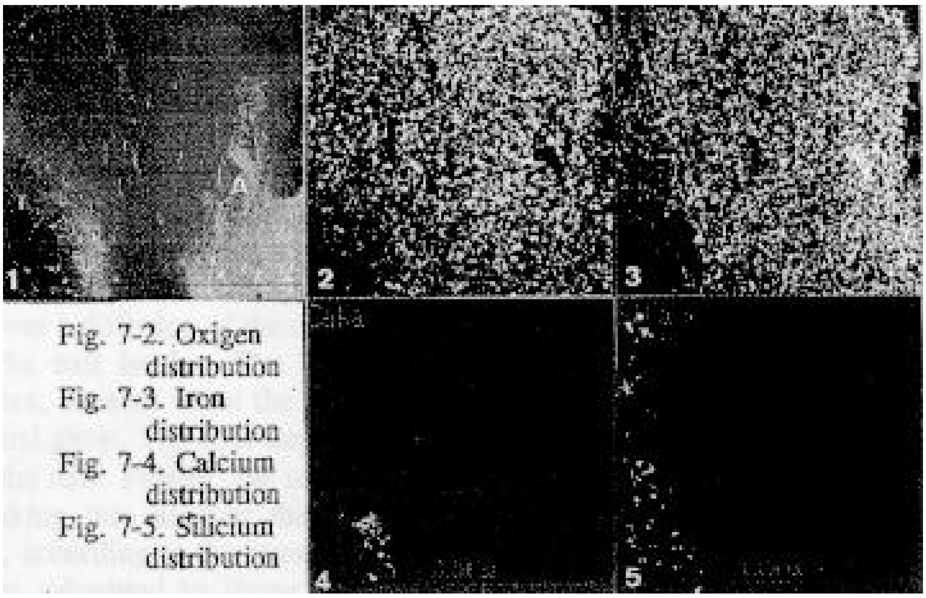
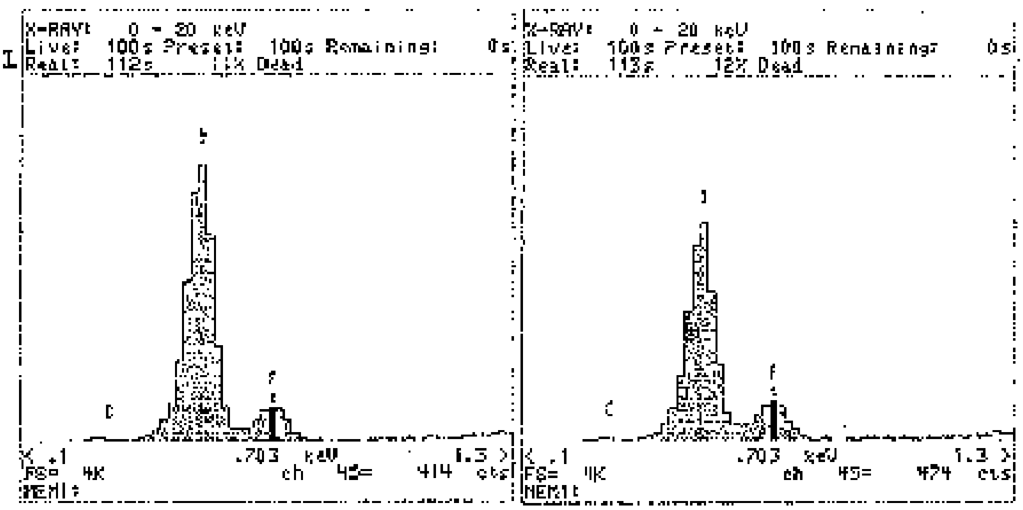


Fig. 7-1. Mineralization of the central longitudinal section of the nail, between the external edge (left) and the inner hole (right): Little metallic area over A.

Analyses of the oxygen variation due to the different degree of oxidation of the sample were performed. The degree of oxidation is detected in the microscope as different tonalities of gray. The diagrams in Figs. 8-1 and 8-2 show this.

The analysis of the elements of the wall of the nail hollow gave only iron and oxygen.

In the samples where sufficiently large metallic areas were observed, the following were analyzed: mineralization surrounding metallic area: Fe and O_2 (Fig.9-1); metallic area: Fe, C (trace) (Fig.9-2); cementite chain: Fe, C (Fig.9-3); and ferritic grain: Fe (Fig.9-4).

8-1


8-2

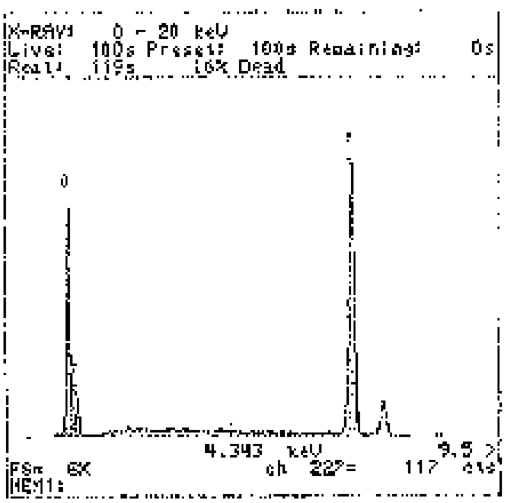
Fig. 8-1. EDS spectrum of mayor elements in a high oxidated stage.
Fig. 8-2. EDS spectrum of mayor elements in a less oxidated stage.

Interpretation

In the study underway we want to show the repeated appearance of pearlitic structures surrounding the central hollow of the nails, the presence of charcoal in the walls of these hollows, and traces that seem to be martensite on the external surface of a nail. These facts, considering the size of the nails, encourage us to launch the hypothesis of forging conducted according to the following steps: 1) Lamination by forging of the metal bar, on a bed of powder charcoal, leaving it with a thickness of 0.5 to 1 cm; 2) Covering of this plate with powder carbon; 3) Bending of the plate; 4) Heat treatment to the cherry-red, favoring the internal diffusion of the carbon of the charcoal that has been trapped; 5) Forging of the nail, giving it the definitive form; and 6) Immersion in water.

With the first and third step, the forging of the nail is simpler and easier. The second step involves a diffusion of the carbon, making something like a carburation, which made the core of the nail harder. The fourth step would have been no problem for the ancient ironworkers, because when the steel reaches the critical transformation temperature it gives off a special glow. The fifth step would be very short, just the time needed to give the final shape to the nail. Finally, the nail would be quenched in water.

Taking into account that time and temperature are the decisive factors for heat treatment, according to the remains of structures found we can say that the heating time that a nail was submitted to seems insufficient, because the austenitic critical transformation temperature did not reach the core of the piece. This, together with sort forging work, explains why a hollow surrounded by a ferrite-pearlitic structure was found in the center of the nails. The subsequent quenching conducted on a piece that had suffered an incomplete austenization, produced a martensitic surface layer and gave the nail surface hardness. If, just as we saw the Fe-C structures reproduced in the center of the nails, we see surface tempering structures with sufficient frequency, we can be sure that in the centuries studied the ironworkers in the northeast of *Hispania Tarraconensis* were using heat treatments with a change in composition to give the worked pieces the required properties.

9-1


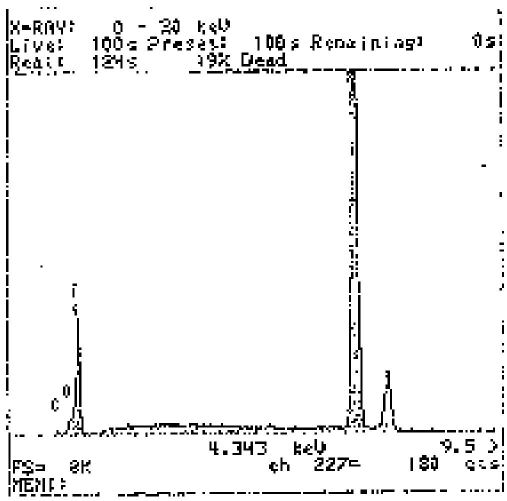
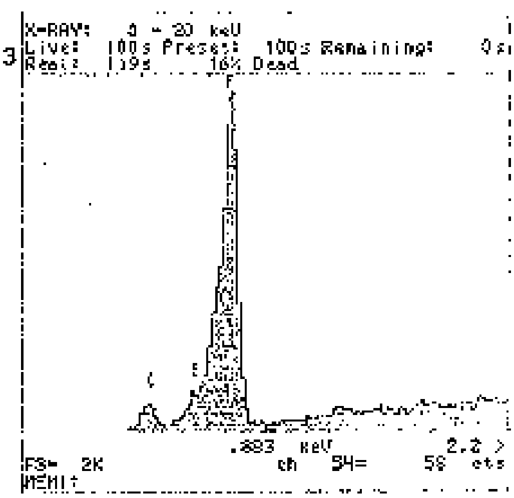
9-2


Fig. 9-1. EDS spectrum of mayor elements in a matrix mineralizated with metallic fragment.

Fig. 9-2. EDS spectrum of mayor elements of the metallic nucleus.

9-3


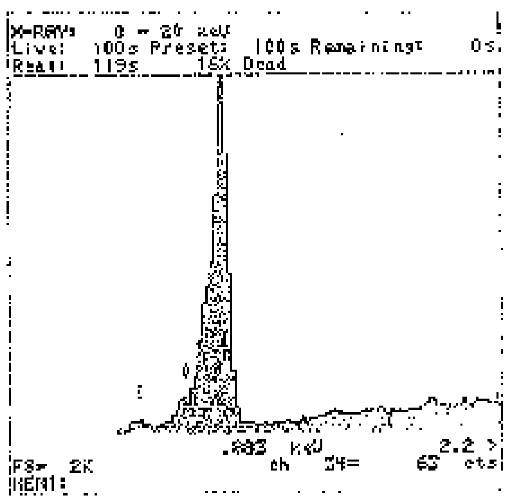
9-4


Fig. 9-3. EDS spectrum of mayor elements in a cementitic chain.

Fig. 9-4. EDS spectrum of mayor elements in a ferritic grain.

CONCLUSIONS

The ancient metallurgical technique was simple and did not require very sophisticated facilities. The ironworker could not control the temperature of the wearth of forger, but by experience he knew the color that the iron had to reach for his work. The micrographic structures observed has led us to conclude that the Roman rural ironworker knew and practiced most forging techniques, but the less than optimum culmination of the technical processes shows that, though specialized, the work was not highly qualified. Furthermore, the standardization of the technical processes and the homogeneous range of final products suggest that the rural ironworker was more a workman repeating acquired techniques and practices than a craftsman providing different solutions to specific problems.

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