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Mineralogical investigation of stone implements. Lerna Archaeological site. Greece.

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1. Location of Lerna archeological site,

The Lerna archaeological site is located about 12 km from Argos near the small village of Myloi (Fig. 1). The site is a hillock oval in shape measuring about 160-180 m and rising 5.5 m above the surrounding plains. In the years 1952-1957 exploration of the site was conducted by J.L. Caskey (1960) together with a large group of coworkers representing American School as well as Archeological Council. Caskey's exploration of the site showed the presence of Neolithic as well as Bronze Age archaeological horizons containing settlement structures and a great amount of archaeological finds (pottery, bones, stone implements etc.).

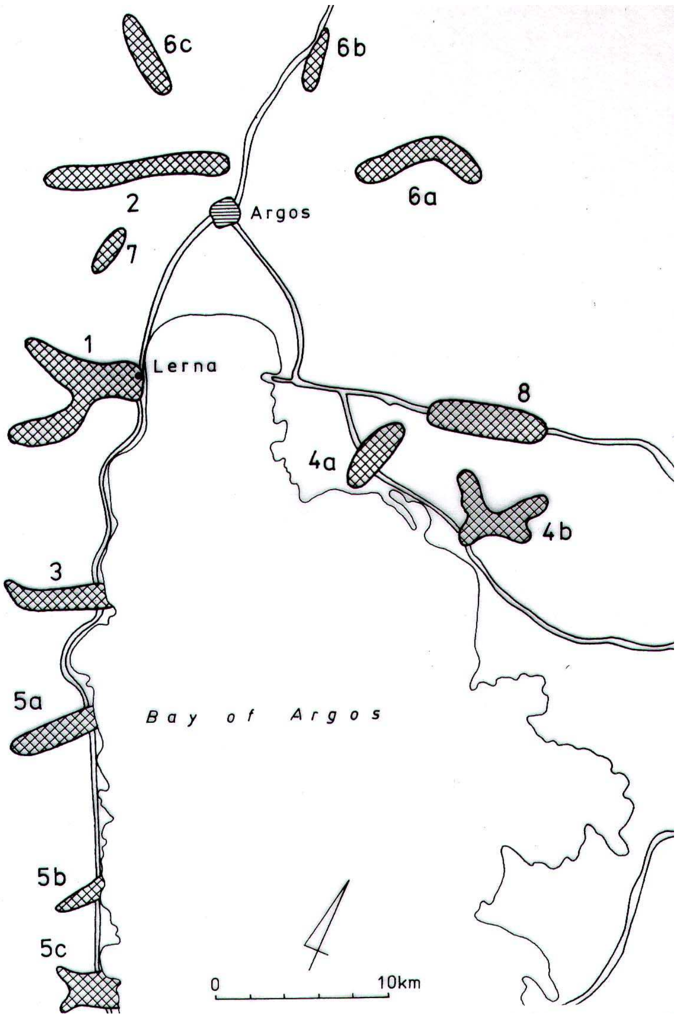


Fig. 1 Map of Argos Bay showing the location of the Lerna Araeological site and the location of tested outcrops.

The paper is devoted to the analyses of the stone inventory present in the investigated archaeological layers and determination of the sources of stones used for the production of the implements. The data from field and mineralogical analyses were used for the determination of directions of the transport of the stones to the archaeological site.

Investigation of stone implements and field works was through the courtesy of prof. Elizabeth Banks - Kansas University, USA - former assistant of prof. Caskey.

2. Material and methods of the investigation

The following investigations were performed:

1. Macroscopic identification of the stone implements from the archaeological site
2. Field survey to determine the areas of presence of the rocks used for production of implements.

a. Analyses of the sediments filling up the valleys of rivers in the Gulf of Argos
b. Determination of the areas of occurrence of rocks (natural outcrops) used for preparation of implements discovered in the site

3. Mineralogical investigation of stone implements and rocks collected during field works

a. Microscopic description with the use of polarizing light microscopy. The samples for this investigation were prepared in the form of thin sections (0.02 mm).
b. Determination of the mineral composition of these samples. About 500 grains of the minerals were identified in each investigated sample with the use of the micros-cope. The results were converted to percentages and collected in tables
c. Determination of the grain size composition of the samples. For each sample the diameter of about 500 grains was measured under the microscope. The results were converted to percents and collected in the tables.
d. X-ray identification of mineral composition of samples. Samples were tested using X-ray diffractometer DRON 2.5 and Cu K monochromatized radiation. The samples for the analyses were powdered. Identification of the mineral phases was made with the use of XRAYAN computer program.
e. Infrared spectrofotometric analyses were performed for selected samples with the use of SP 90 (Zeiss) spectrometer. Powdered samples were mixed with KBr and prepared in the form of tablets. Obtained curves were identified with the use of a computer program.
f. Some samples were tested chemically with the use of atomic spectroscopy (ASA equipment, Philips PU 9100X). Samples were dissolved in acids mixture. The sediment obtained after evaporation of the acids mixture was dissolved in HCL.

Results of microscopic investigation were used for the comparison of rock implements from the site and rocks from natural outcrops as well as for reconstruction of the ruts of the transport of stones to the site at various phases of site occupation.

3. Results of investigation,

a. Mineral and petrographic identification of stone implements from the Lerna archaeological site,

List of the rocks (no. and symbol) from Lerna archaeological site

Sedimentary rocks

1. breccia............……………......Br
2. sandsrone......…………...........Sa
3. micaceous sandstone…........MSa
4. sandstone with Fe oxides….FeSa
5. calcareous sandstone.……...CaSa
6. silty sandstone...……….......SiSa
7. siltstone..........………… ... Si
8. limestone.........………........Li
9. litographic limestone...…... LLi
10. bituminous limestone…....BLi
11. silty limestone......……......SiLi
12. hornstone............………..Ho
13. spherositerite.......……......Sp
14. claystone ....………...Cl

Magmatic rocks

15. basalt...............................Ba
16. diabaze............................Di
17. microgabbro.....................MGa
18. andezite..........................An
19. pummice.........................Pu

Metamorphic rocks

20. serpentinite.......……..…....Se
21. serpentinized gabbro.……..SGa
22. serpentinized microgabbro SMiGa
23. serpentinized peridotite…..SPe
24. gnaiss..............…………...Gn
25. serpentinized diabase…......SDi
26. nephrite......…………...........Ne
27. phyllit..........…………........Ph
28. steatite..........…………......St
29. marble.............………......Ma

Minerals

30. hematite............................H
31. goethite...............................G
32. calcite............…………...Ca
33. onyx............……….......Ox
34. jasper..........……………......Ja
35. turquoise...........………..Tr
36. fluorspar..........………....FSp
37. mountain quartz.......……MQ
38. quartz...............………....Q
39. ametyst.............………Am
40. malachite..........………Ml.

A. Macroscopic description.

I. Magmatic rocks,

Investigations showed the presence of following magmatic rocks: microgabbro, diabase, keratophire, andezite, obsidian and volcano pummice.

Microgabbro is represented by dark, near black medium crystalline rock composed of pyroxenes and plagioclase (labradore) as well as olivines. Traces of ore minerals are present as additional components. The rock is slightly metamorphosed.

Diabase is a dark greenish rock with fine crystalline structure. The rock is composed of plagioclases pyroxenes and ore minerals (mainly Fe oxides).

Keratophyre is reddish rock with porphyric texture. Feldspars and rare flakes of the biotite are seen in subcrystalline mass.

Andesite is rock gray in color, with porphiric texture. Piroxenes, amphiboles and fenocrystals of plagioclases are seen macroscopically. The rock is not weathered.

Obsidian is the volcanic glass black, dark grey color. It shows transparence especially when it is present in the form of small flakes. Some variations of obsidian contain traces of linear structures as well as small mineral inclusions.

Pummice is white in color, with fine porous structure. The size of the pores is up to about 1.0 mm.,

II. Sedimentary rocks,

Breccia represents sedimentary rock reddish in color. It is composed of sharp grains of limestones cemented with fine calcitic masses containing admixtures of Fe oxides.

Sandstone. Several types of sandstone were present in the inventory from Lerna. Typical sandstone is fine or coarse grained, light in color and composed of quartz.

The following types of sandstones were identified: calcareous sandstone containing calcitic matrix, ferrigenous sandstone containing admixtures of Fe-oxides, light micaceous sandstone composed of quartz and small flakes of muscovite.

Siltstones are light beige in color, sometimes showing traces of linear structure. They contain clay admixtures present mainly in the form of a cementing substance.

Claystone present in the inventory is light yellow in color. It is soft and contains a smectite admixture. This is confirmed by the reaction of the claystone with water.

Sandy limestone is light gray in color. The limestone contains an admixture of about 30-35 % of quartz grains.

Silty limestone are represented by limestone of light grey color and containing an admixture of grains of detrital material ranging between 10 to 30 %.

Limestones present in the inventory of the Lerna site are differentiated. Three types of limestones are most frequent i.e.

light beige limestone out of sedimentary structures,

litographic limestone light yellowish in color with a very solid texture and occassional stilolites

black, bituminous limestone giving off characteristic odor

Hornstones are not frequent in the inventory. Small flakes of this rocks are present among chipped material. Hornstones are reddish, brownish-red and dark gray in color. Sometimes they contain small veins, light in color, filled up with secondary calcite.

Spherosiderites are present as regular, concretions. They are composed of two parts: external and internal .The internal part contains concentrations of Fe carbonates with a small admixture of clay, light yellowish in color. The external part is composed mainly of clay with only a small admixture of iron minerals. The surface of the spherosiderites is dessicated .

III. Metamorphic rocks,

Serpentinized peridotite is a darkgreen color showing elements of perodotite structure. The rock is hard, composed mainly of serpentine minerals.

Serpentinized gabbro is very similar to the serpentinized peridotite. The rock shows variability of color from black to dark-green. Fragments of this rock contain elements of primary gabbro texture.

Serpentinized diabase belongs to a group of metemorphised alcaline, magmatic rock. It is green in color and contains elements of fine crystalline texture typical for diabase. The degree of the metamorphism of the diabase is differentiated.

Serpentinites are represented by a group of rocks green in color, composed of fibrous metamorphic minerals such as zoizite, tremoliteactinolite, chlorites, and sometimes containings amphiboles as well as pyroxenes and ore minerals.

Implements made of gnaiss are rare. They are represented by a light rock of blastic texture and delicate linear structure.

Quartzites are light in colors, with fine up to medium grained texture. They are composed of quartz grains cemented with secondary crystallized silica.

Phyllite shows typical parallel structure and perfect cleavage. It is composed of calcite and muscovite. It sometimes contains admixture of serpentine minerals as well as traces of ore minerals.

Marbles are light, light beige, light gray in color with occasional dark laminae. They are fine crystalline, composed mainly of calcite. Steatite is a rock composed mainly of talc. It sometimes contains, an admixture of chlorites (green), iron minerals (dark modification) and shows traces of linear structure. It is soft.,

Jasper present in Lerna materials is a hard siliceous rock red in color. The rock is cut by light siliceous, secondary veins.,

IV. Minerals

Malachite and azurite are present in the form of mixtures. They are fine crystalline, green-blue in color.

Hematite is medium or coarse crystalline. After powdering it is cherry red in color. Fragments of this mineral, in the inventory of Lerna are relatively hard and polished in the form of cube or irregular fragments (coarse crystalline hematite).

Goethite makes up mixtures with hematite where the two minerals occur in varying proportions.

Smoky quartz is brown in color present in the form of natural small crystals with perfectly preserved walls.

Mountain quartz is present as a small polished bead.

Amethyst is typical violet in color and was used as a bead.,

Onyx (sardonyx) is present in the inventory in the form of beads. This mineral is reddish. Some beads show different shades of red.

Turquoise is represented by one small fragment. The mineral is bluish green in color, cut by small veins filled with brownish minerals.

Fluorspar is represented by small rounded beads. The mineral is transparent and clean.

Talc is present in the inventory as an irregular grain of natural shape. The mineral is dark brown in color.

B. Microscopic examination of selected implements

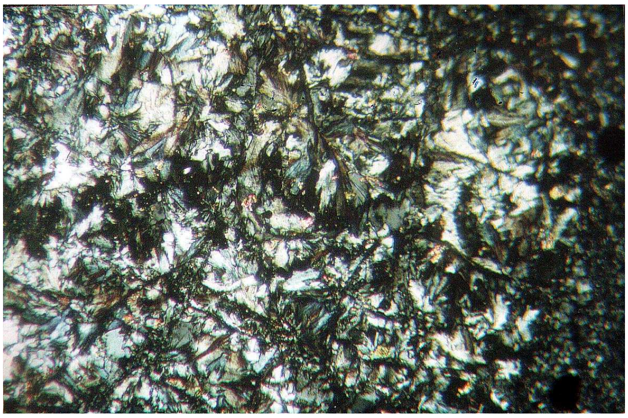
Magmatic rocks.

1. **Diabase** (inventory no. 9).

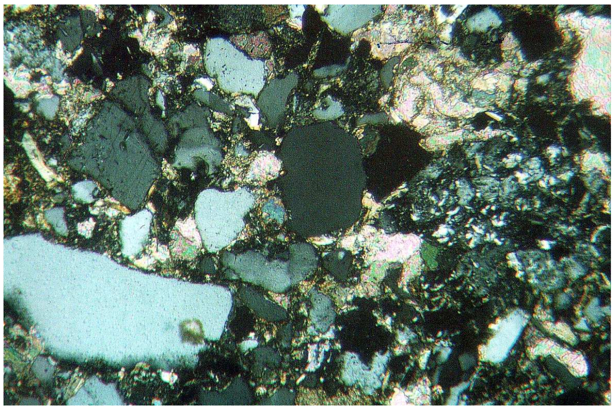
The rock shows very fine crystalline texture and a compact structure. It is composed of metamorphic minerals represented by plagioclases, zoizite, quartz. Chalcedony and opaque minerals are present as an admixture. (Photo. 1A).

2. **Diabase** (inventory no. G 146).

Microscopic character of this sample is very similar to sample no. 9.



A



B

Photo 1 A – weathered diabase (inventory no. 9). B – sandstone (inventory no 4). Polarizing light microscope, polaroides X, magnification 80 x.

Sedimentary rocks,

1.Sandstone (inventory no. 4)

The rock shows medium grained texture and disordered structure. Quartz and rocks fragments (sedimentary and magmatic) are main, detrital components of the sandstone. Grains of these minerals are cemented by fine calcite (Photo. 1B).

4. **Sandstone** (inventory no.25).

Under the microscope the rock shows mixed medium-fine grained texture and disordered structure. It is composed mainly of quartz and small rocks fragments (mudstones, limestones). Grains of these components are cemented with recrystalized calcite.

5. **Siltstone** (inventory no. GE I).

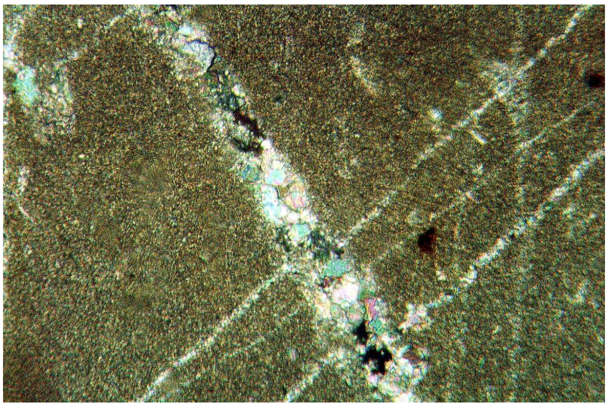
The rock has a fine grained texture and a disordered structure. It is composed of two main components i.e. sharp quartz grains and cementing calcite (carbonates). Calcitic cement is of a basal character. Grains of this mineral are recrysta-llized. Together with quartz and calcite there are muscovite, feldspars, glaukonite, and micas.

6. **Limestone** (inventory no.18).

The rock represents pure, micritic limestone cut with thin veins of secondary calcite (Photo. 2A).

7. **Limestone** (inventory no. 74).

The rock is composed of calcitic micrite building a homogeneous background. Small skeletons of foraminifera are dispersed in the calcite. The internal part of the skeletons is filled with medium crystalline calcite.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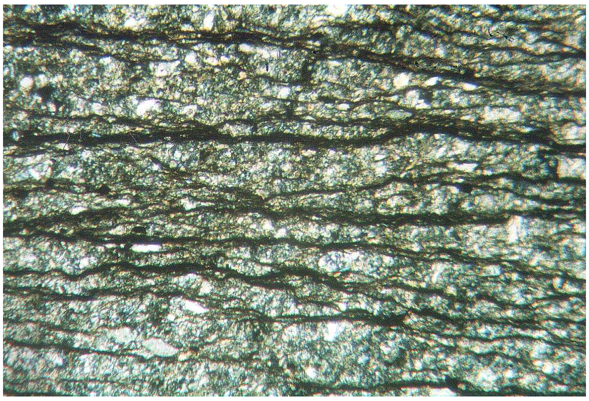

B

Photo 2 A-limestone cut with veins (inventory no.18). B - phyllite (inventory no. 72) with parallel structure. Polarizing light microscope, polaroides X, magnification 80 x.

Metamorphic rocks

8. **Serpentinite** (inventory no. ADA765).

The rock represents strongly changed magmatic rocks with fine texture and an irregular, massive structure. It is composed of zoizite, amphiboles and quartz. Micas, pyroxenes and feldspars have been identified as accessory minerals.

9. **Dacyte** (inventory no. 53).

This sample was macroscopically identified as serpenitinite. Under the microscope the rock shows fine crystalline texture and a homogeneous structure. It is composed of feldspars, quartz and ore (opaque) minerals. Secondary carbonates and minerals representing the tremolite-actinolite group were determined.

10. **Phyllite** (inventory no. 72).

The texture of the rock is fine crystalline, its structure parallel. The rock is composed of recrystallized calcite intercalated by thin laminas composed of metamorphosed clay minerals represented now by light micas (muscowite). The rock shows perfect cleavage due to the presnce of regular parallel laminae composed of micas. Additionally quartz, zoizite, opaque minerals and traces of organic substance were determined (Photo. 2B).

Results of microscopic analyses are listed in the table no. 1, 2.

C. Results of X- ray analyses

X-ray analyses were performed for selected samples represented by diabase, sandstone, serpentinite and phyllite (Fig. 2).

1. **Diabase** (inventory no. 9)

X-ray pattern documents the presence of the following , minerals: quartz, plagioclases, zoizite and chlorites.

2. **Sandstone** (inventory no. 45),Quartz and calcite are the main components of rocks. A weak peak of diffraction (d hkl = 3.18 A) documents small admixture, of plagioclases.

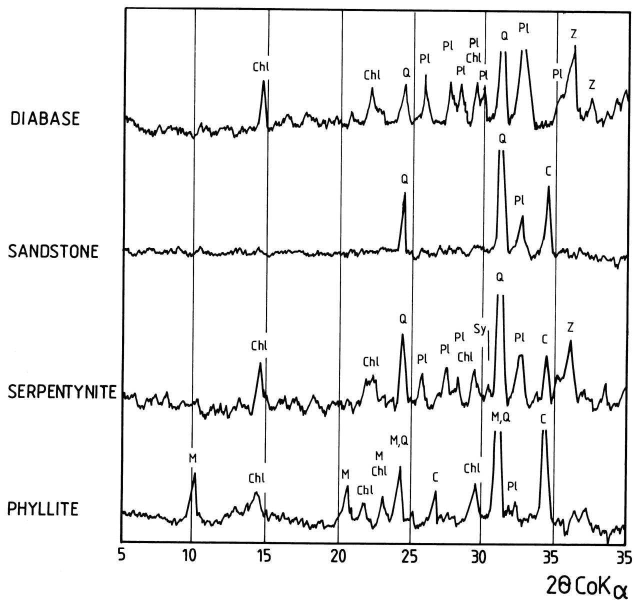


Fig. 2 X-ray patterns of stone implements form the Lerna archaeological site

3. **Serpentinite** (inventory no. 53)

The mineral composition of this sample documented by X-ray diffraction is similar to that of diabase (sample 1). Quartz and zoizite as well as chlorites are the main components of the rock. Plagioclases and sylimanite have been identified as accompanying minerals.

4. **Phyllite** (inventory no. 73)

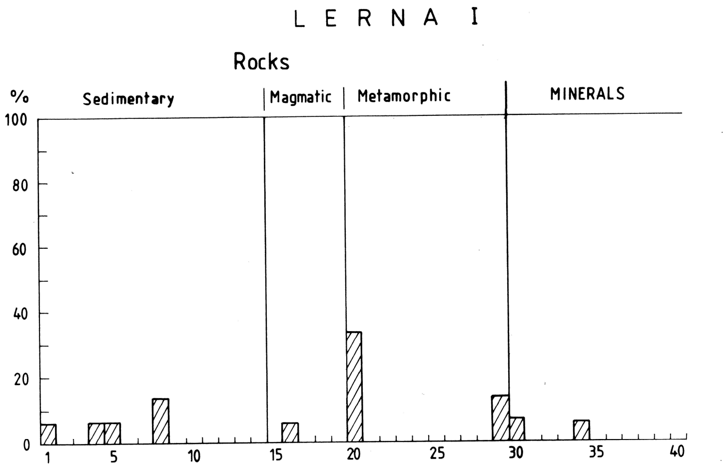
X-ray identification showed the presence of mainly calcite and muscovite Traces of plagioclases and chlorites were identified as minor compounds.

D. Petrographic composition of stone inventory

After identification the rocks and minerals present in the inventory were ordered into archaeological horizons by E. Banks and C. Zerner. On this basis statistic of the distribution of various types of rocks in archaeological horizons have been done. The statistical results are indicated for each archaeological horizon on the diagrams.

I. Phase Lerna I

Black obsidian is absolutely the most frequent stone implement in this phase. It originated from the island Milos. Serpentinites are rocks most frequently occuring in nventory of Lerna I (not counting obsidian). Together with serpentinite an admixture of about 13 % of marble was identified (Fig. 3A). Among sedimentary rocks fragments of limestones constitute about 13 % of the inventory. They are present together with breccia and sandstones which contain an admixture of iron oxides and calcite. Diabase is the only magmatic rock. Among the minerals hematite and jasper were identified.



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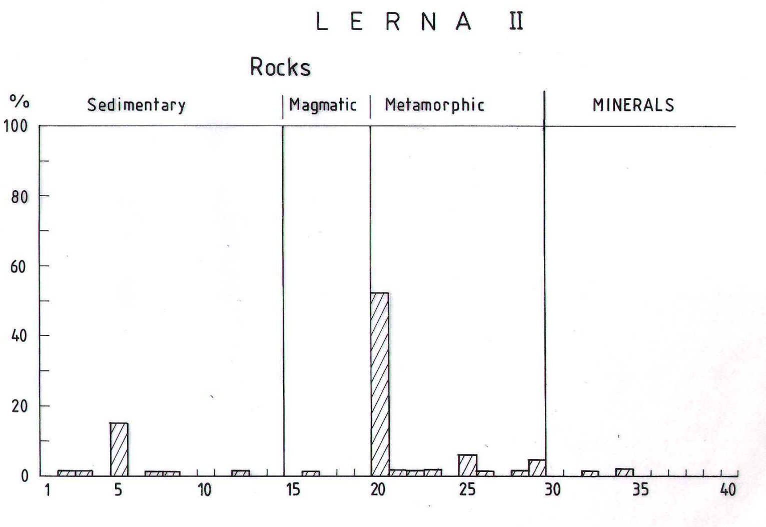


B

Fig. 3A,B. Frequency of rocks in archaeological horizon A - Lerna I, B - and Lerna II.

II. Phase Lerna II

The mineral and petrographic composition of implements from this archaeological level is complex. Serpentinites are the dominant type of rock (Fig. 3B), but together with them small quantities of serpentined gabbro, microgabbro, peridotite and diabase were identified. Additionally nephrite, steatite and marble have been identified. Calcareous sandstone is the predominant sedimentary rock. It is present in the inventory together with other types of sandstones, siltstones and limestones. Diabase is the only magmatic rock present in the inventory of this archaeological horizon.

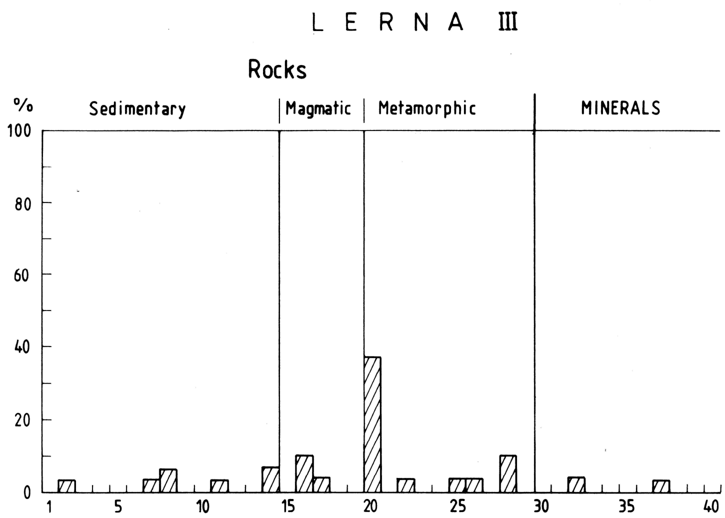
Calcite and jasper have been idenitfied as accessory minerals.

III. Phase Lerna III,

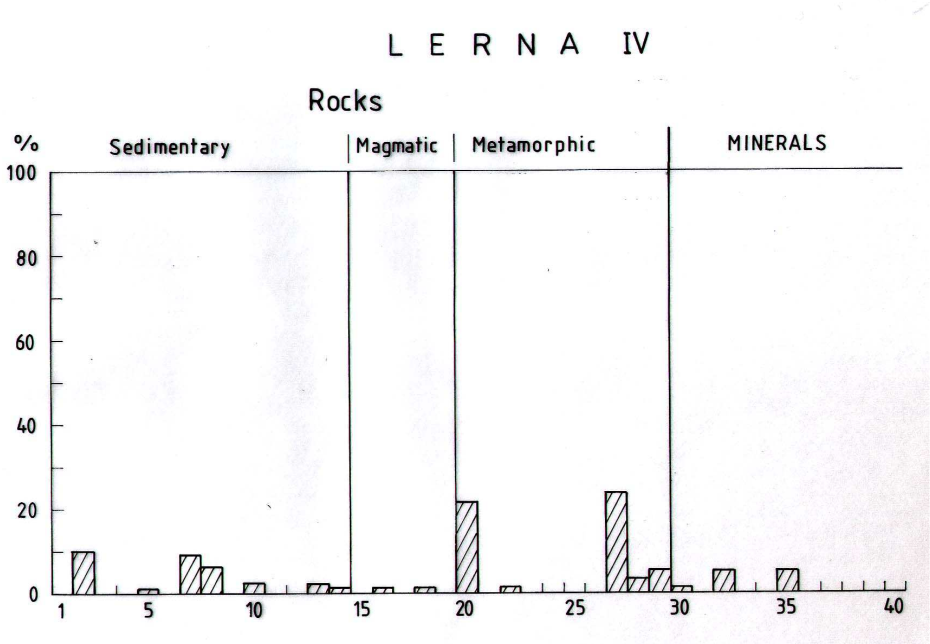
Serpentinite is again the most frequent rock in this archaeological horizon (Fig. 3c). Among other metamorphic rocks the following types have been identified: serpentinized microgabbro and diabase, nephrite and marble., Limestone and claystone are dominant in the group of sedimentary rocks. They are present together with siltstones and silty limestones and limestones.

Diabase and microgabbro were identified in the group of magmatic rocks. Calcite and mountain quartz were identified in the group of minerals.

IV. Phase Lerna IV



C



D

Fig. 3 C, D. Frequency of rocks in archaeological horizon C - Lerna III, D - Lerna IV.

The rock inventory of this horizon is much more complex than these of Lerna IIII. Serpentinite and phyllite are the most frequent rocks in this horizon. Together with these rocks, the following metamorphic rocks: serpentinized microgabbro, steatite and marble have been identified (Fig. 3d).

Sedimentary rocks are represented mainly by sandstones, siltstones and limestones. Bituminous limestone, shperosiderite, sandy claystones are present as accompanying rocks.

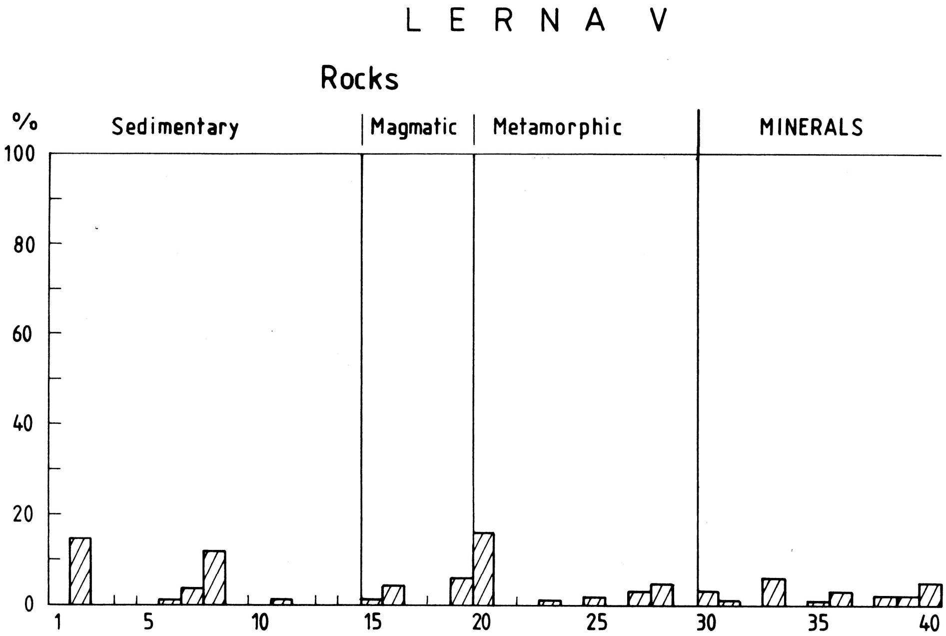
Hematite, turqouise and calcite were identified in the group of minerals.

V. Phase Lerna V

Serpentinite, just as in the preceding levels, is the main type of rock. Together with this rock other metamorphic rocks are present namely: serpentinized peridotite and diabase, phyllite and steatite (Fig. 3e).

Sandstone and limestone are the most frequent rocks in the group of sedimentary rocks. They occur together with silty sandstone, siltstone and silty limestone.,

Among minerals hematite, goethite, onyx, turquise, fluorspar, quartz, amethiste, malachite were identified.



E

Fig. 3 E. Frequency of rocks in archaeological horizon Lerna V.

E. Evolution of stone utilization during Lerna I- V phases of occupation

Petrographic analyses of stone inventory from Lerna documents, changes of proportion between various types of stones during the functioning of the site.

Sedimentary rocks

Sandstone, calcareous sandstone, siltstone and limestone have been taken into consideration (Fig. 4A). Analyses of the frequency of these rocks showed systematic growth of the amount of sandstone. Calcareous sandstone was utilized mainly in the Neolithic (Lerana I, II) and only slightly, during Lerna III phase. Later this rock has not been used. Siltstone was utilized during Lerna IIV phases with maximum utilization during Lerna IV. Limestone was used in all phases. Its maximum use was determined at Lerna I and Lerna V.

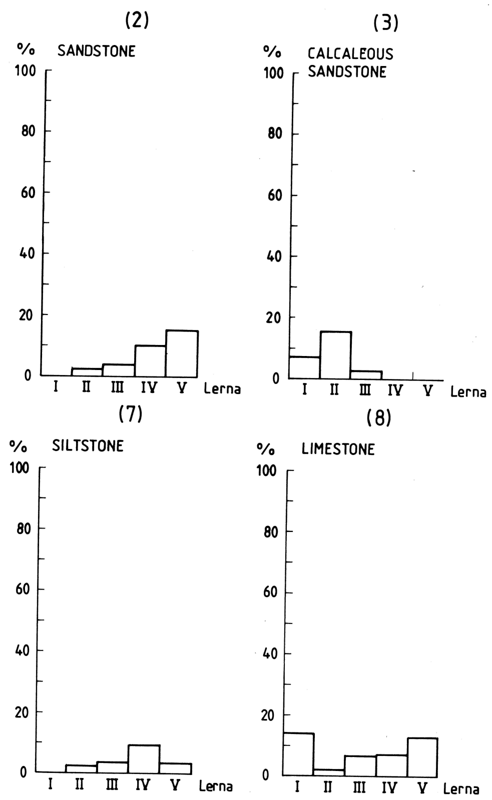


Fig. 4 Frequency of selected sedimentary rocks in archaeological horizons Lerna I-V

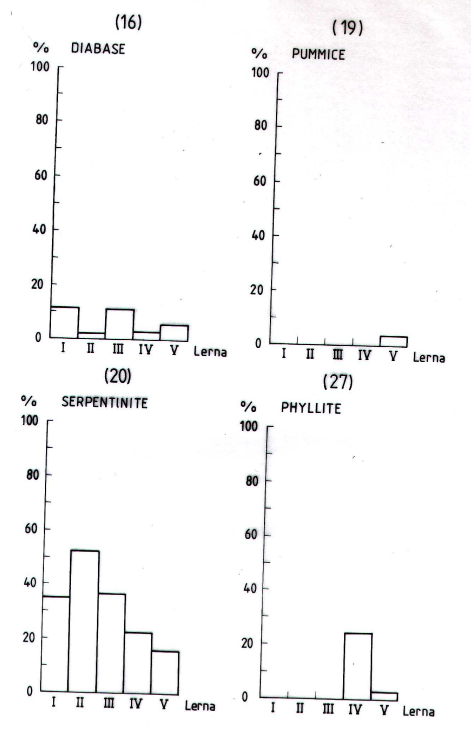


Fig. 4 B. Frequency of selected magmatic and metamorfpic rocks in archaeological horizons Lerna I-V

Magmatic rocks

Typical magmatic rocks are not very frequent in the inventory from Lerna. This can be explained by the low frequency of these rocks in the tested area near of the site. Diabase and pumice are most frequent. Diabase is present in all the archaeological layers but pumice appears only in Lerna V (Fig. 4B diabase, pumice).

Metamorphic rocks

These rocks together with sedimentary rocks are most frequent in the Lerna inventory. Serpentinite is the dominant rock (axes). The quantity of this rock is highest in Lerna II (Fig. 4b serpentinite, phyllite). Phyllite appears only in Lerna IV and V horizons.Steatite was recorded starting from phase Lerna II. Marble appears occasionly in Lerna I, II and IV (Fig. 4C).

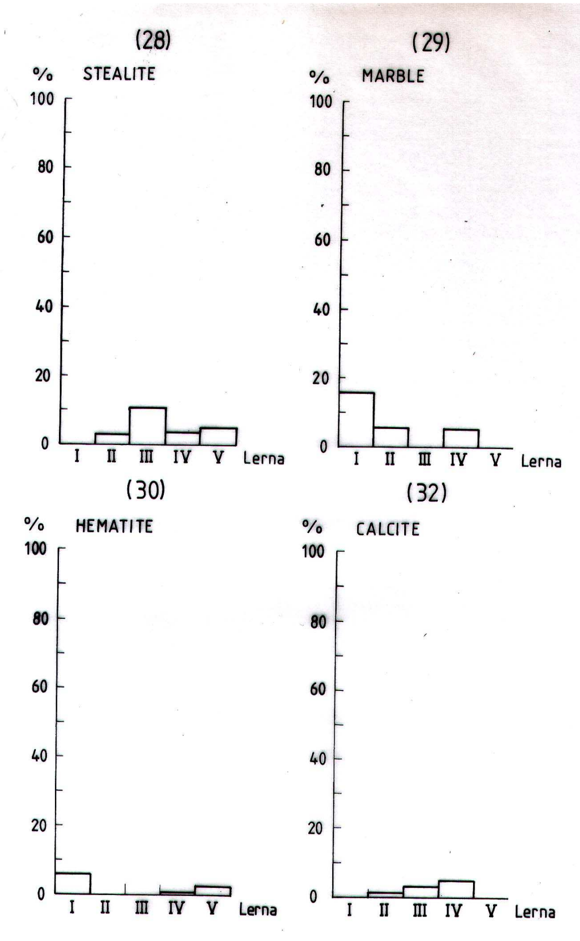


Fig. 4 C. Frequency of selected metamorphic rocks and minerals in archaeological horizons Lerna I-V

Minerals

There are not many minerals at older archaeological phases. They start to be more frequent at younger phases of occupation. Hematite is present in Lerna I, IV and V. Calcite in Lerna II, III, IV (Fig. 4C). Jasper was found in Lerna I and II. Turquoise is present in Lerna IV and V but dominates in Lerna IV. The presence of amethyste and malachite was confirmed only in Lerna V horizons (Fig. 4D).

Varying frequencies of tested rocks and minerals in archeological horizons of Lerna is the documentation of different functions of the site and especially the various interests of the inhabitants. Obtained data concerning frequency of the presence of rocks should be compared by archaeologists with the frequency of the occurrence of various implements made of different rocks. This comparison would show the relation between rock types and functions of implements.

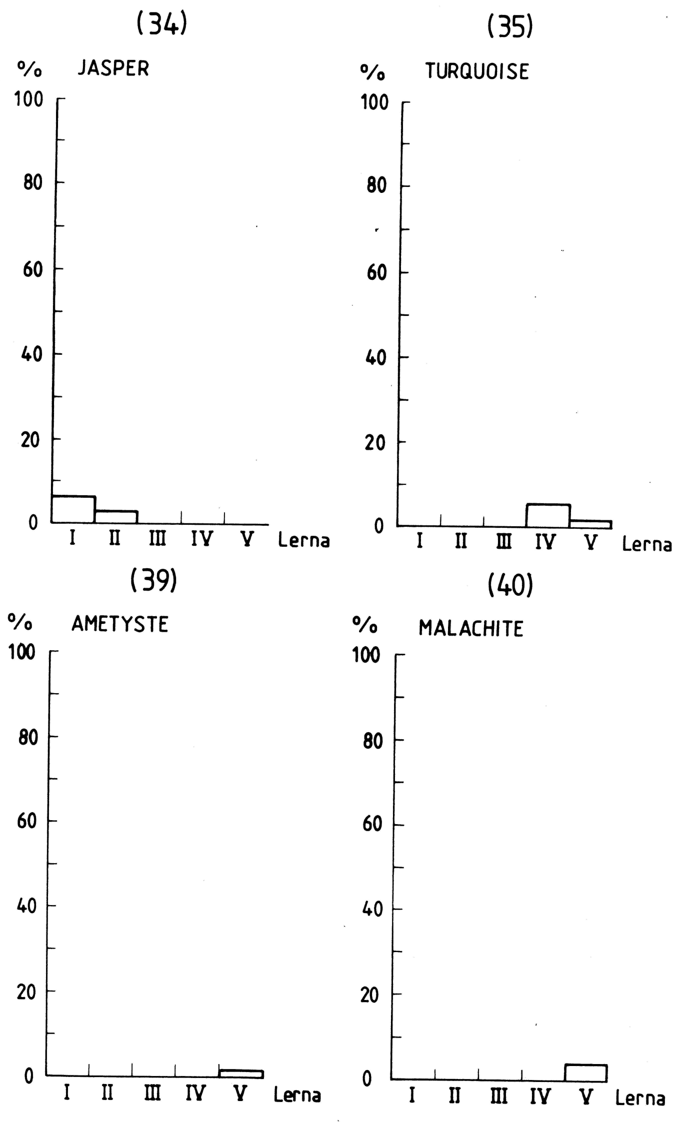


Fig. 4 D. Frequency of selected minerals in archaeological horizons Lerna I-V

4. Geology and morphology of the Gulf of Argos

Morphology of the Gulf of Argos is the result of petrographic composition of the rocks as well as the consequence of tectonic activity in the area Zangger (1991). The Gulf is surrounded by high mountains. Rivers show typical mountain character and intensive erosion of rocks. The material eroded in the mountains is deposited on the small flat areas in the coastal belt. The oldest rocks in the area of Argos are represented by metamorphised Carboniferous formation. Rocks of this formation are located SW of the Lerna site near Tripoli and in the region of Argilista about 25 kn to the W of Argos. They are represented by serpentinites, phyllites, metamorphic alcaline rocks (gabbro, diabase), marbles, chlorites, hematite, goethite. Rocks of the Permian formation are present about 20 km to the E from Tolo. They are represented by keratophyres, and tuffs.

Triassic sediments are located mainly in the northern and eastern part of the Gulf of Argos. They are represented by different types of limestones containing intercalations of red and black hornstones. Jurassic deposits occur in small areas. They are represented by limestones, claystones and weathered igneous rocks (alcaline ofiolites) as well as sandstones. The most important sources of these rocks are situated 3040 km to the NE of Argos.,

Cretaceous formations are the most common formation in the area of Argos, building a greater part of the mountains in the southern part of the Gulf of Argos. They are represented by various types of limestones, sandstones and siltstones as well as by silty limestones and sandy limestones. Palaeogene is represented by limestones, dolomites, flysch sediments and bouxites. Flysch sediments are composed of siltstones, sandstones and limestones intercalated with claystones cherry red and green in colour.

Pleistocene sediments are present at many places in the region of Argos. They are composed of gravels, conglomerates, sands, muds and clays. On the sea shore marine breeccia located some meters above the present level of the sea water were observed.

Holocene sediments are present mainly in morphological depressions on flat areas. They are composed of conglomerates, cones of debris, torrential deposits containing gravels, sands and terra rossa.

5. Sources of the rock - field survey,

The aim of the investigation was to determine sources of raw materials as well ruts of migration of the inhabitants of Lerna, as found at other archaeological sites (Pawlikowski 1992, 2001, 2002, Koumuzelis et all 1996, 2001, Kozlowski et all 1996) A field survey in order to determine the sources of stones present at the archaeological site used as implements was conducted in two stages.

The first stage of the investigations was conducted in the valleys of the rivers of the Gulf of Argos where the composition of river gravels from surrounding areas was identified petrographically.

The second stage the survey was devoted to the exploration of the mountains and natural outcrops of rocks mentioned above. The survey was conducted in the following areas (Fig. 2, table 3).

1. region of Lerna, 2. Valley located NW from Argos, 3. region of Astros, 4. areas N and E from Tolo, 5, region Lerna Tiros, 6. regions Prosima, Fihti, Shinohori, 7, region of Kefalari, 8. valley E of Nafplio.

The composition of rocks present in these areas is given in table no. 3.

The second stage of the survey investigation was conducted in the mountains. Natural outcrops of the following rocks were discovered:

I**. Magmatic rocks**

Rock	Region
1. diabase -	region 5 c
2. keratophyre -	region 4 b

II. Sedimentary rocks

Rock	Region
1. breccia -	region 1,2,3
2. calcareous sandstone -	region 1,2,7
3. siltstone -	region 1,2
4. claystone -	region 7
5. silty limestone -	region 1
6. limestone -	region 18
7. litographic limestone -	region 2
8. black limestone -	region 1,3
9. hornstone -	region 1, 2, 3, 4
10. red radiolarites -	region 4a, 8

III. Metamorphic rocks

Rock	Region
1. serpentinized diabase -	region 5c, 6,
2. serpentinized microgabbro -	region 5c, 6
3. serpentinite -	region 5c, 6
4. nephrite -	region 5c

5. phyllite - region 2
6. marble - region 1, 2, 3

IV. Minerals

1. Calcite - region 5b,

Additionally different types of siliceous rocks were found in river terraces in area 6b and 8. They are represented by:

1. red hornstones
2. gray hornstones
3. gray flints
4. dark gray flint

Sources of siliceous raw materials

The area of the occurence of red radiolarites is relatively large. These rocks are present on the surface and generally show good technological features.

Some fragments of chalcedones and agates showing good technological parameters were found in area 4a and 8. Chalcedones are light gray in color. Agates are rare gray and red in color. Both types of minerals are present in form of river pebbles up to 23 cm in size.

c. Mineralogical and petrographic identification of rocks from natural outcrops

Rocks for mineralogical investigation are collected, in list no. 4.

A. Microscopic analyses of selected samples from natural outcrops.,

Magmatic rocks

1. Diabase (XI)

Under the microscope, the rock shows a very similar texture, structure and mineral composition to diabase from the archaeological site (Photo 3A) .

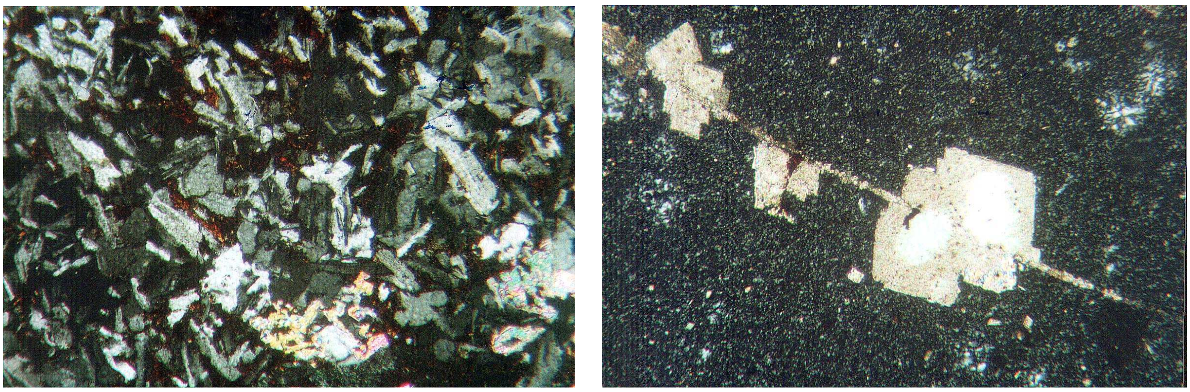
Sedimentary rocks

2. Breccia (II)

The rock is composed of coarse gravels of light, micritic limestone cemented with reddish fine crystalline calcite containing an admixture of red clay (redeposited terra rossa). This type of breccia is very common on the sea coast.

3. Micaceous sandstone (XII)

The texture of the rock is medium grained and its structure is parallel due to presence of orientated flakes of muscovite. The rock is composed of medium rounded grains of quartz, feldspars, fragments of limestones and muscovite. Detrital material is cemented with calcite



A **B**

Photo 3 A- Diabase from outcrop 5c. B –black hornstone from outcrop 3 (see map-Fig. 13). . Polarizing light microscope, polaroides X, magnification 80 x.

4. Calcareous sandstone (XX)

The rock is of mixed, fine and medium grained texture. The structure is disordered. Quartz grains are the main detrital component. Together with quartz, grains of limestones, rare grains of feldspars and glaukonite are observed. The sample is microscopically similar to sample no 25 from the archaeological site.

5. Siltstone (XIII)

Siltstone shows fine grained texture and slightly parallel structure. It is composed of medium rounded quartz grains. Flakes of muscovite and small, perfectly rounded grains of micritic limestone. Grains of these minerals are cemented with fine crystalline, partially recrystallized calcite.

6. Claystone (XIX),

Under the microscope the rock shows very fine texture and parallel structure. It is composed of clay minerals represented mainly by kaolinite and illite making up the background of the rock. Occasionally small, not frequent, grains of quartz are disseminated in this matrix.

7. Sandy limestone (XVII),

This rock is mainly composed of micritic calcite cut with thin veinlets filled up secondarily with crystalline calcite. Quartz grains are disseminated in the calcitic matrix. Grains of glaukonite are rare.

8. Limestone (XVIII),

The rock represents typical micritic limestone cut by secondary fissures filled up with secondary calcite.

9. Limestone (XIV),

Under the microscope the rock shows mixed, micriticsparitic texture and irregular structure. Small, rare concentrations of opaque minerals contain pirite and are disseminated in calcitic matrix.

10. Black limestone (I)

Limestone has mixed, micriticsparitic texture and irregular structure. It contains skeletons of molusca and gastropods as well as other organisms difficult to determine.

11. Red radiolarite (IX)

Radiolarite is composed of opal and chalcedony. Small flakes of micas are dispersed in this matrix (Photo 11).

12. Black hornstone (III)

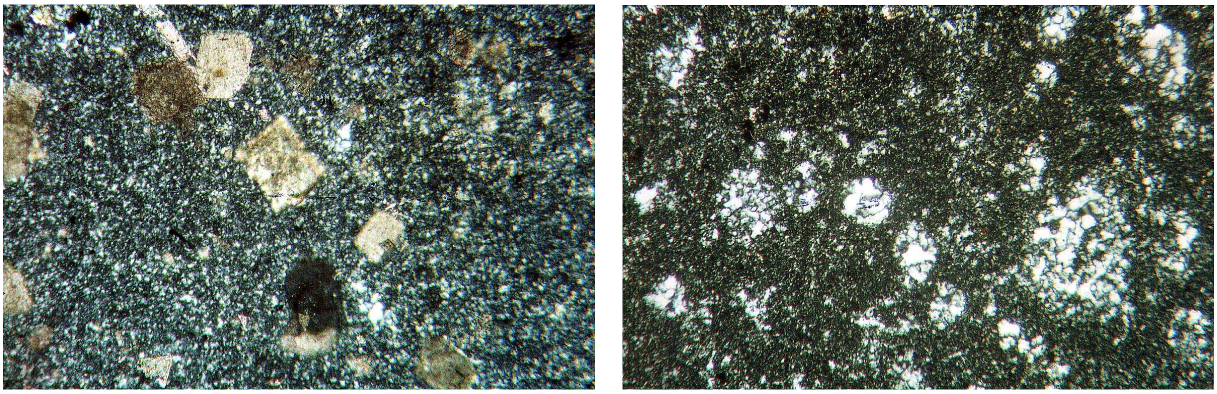
The texture of hornstone is fine crystalline. Its structure is disordered. Chalcedony is the main component of the rock. The rock is cut by veins filled up with calcite (Photo 3B).

13. Grey flint (VII)

The flint is composed of chalcedony. It contains silicified, spiculas of sponga and is cut with calcitic veins.

14. Dark grey flint (X)

Chalcedony is the main component of this flint. The chalcedonic mass is disseminated crystals of calcite (Photo 4A).



A **B**

Photo 4 A - dark grey frint (IX). The chalcedonic mass containing disseminated crystals of calcite. B – structure of red flint (VIII).

15. Red flint (VIII)

Under the microscope, this flint shows fine crystalline texture and irregular structure. It is composed of chalcedony and quartz and concentrations of quartz filling up spacies after microorganisms (Photo 4B). Traces of carbonates as well as opaque minerals can be observed.

Metamorphic rocks

16. Green serpentinite (VI)

The rock is composed of talc, chlorites, seladonite and ore minerals (opaque). The texture is fine blastic and its structure orientated, slightly disturbed. Additionally, traces of tremolite-aktinolite minerals were identified.

17. Metamorphic slide (V)

The rock is composed of flakes of talc cemented with secondary silica. Opaque minerals and traces of zoizite were identified.

18. Phyllite (XV)

The rock has fine blastic texture and orientated, parallel structure. It is composed of thin laminae filled up with fine crystalline calcite intercalated with dark laminae containing micas (mainly muscovite) and organic substance. The rock is very similar to the phyllite from the archaeological site. (sample inventory no. 72).

19. Steatite (IV).

This metamorphic rock is composed of talc in the form of small, compact flakes. Between flakes of talc small grains of opaque minerals can be seen (Photo 17).

20. Marble (XVI),

This rock is recrystallized limestone of coarse crystalline texture and parallel structure. Light laminae are composed of pure calcite. Darker laminae contain an admixture of a substance showing features similar to graphite. Results of microscopic analyses of rocks described above are listed in table 5 and 6.

B. Results of X-ray investigation,

Diabase (sample XI),

The X-ray pattern of this sample (Fig. 5) shows very similar mineral composition to samples of the diabase from Lerna archaeological site. The main components of the sample are: zoizite, quartz and plagioclases. Chlorites were idenitfied as accessory minerals.

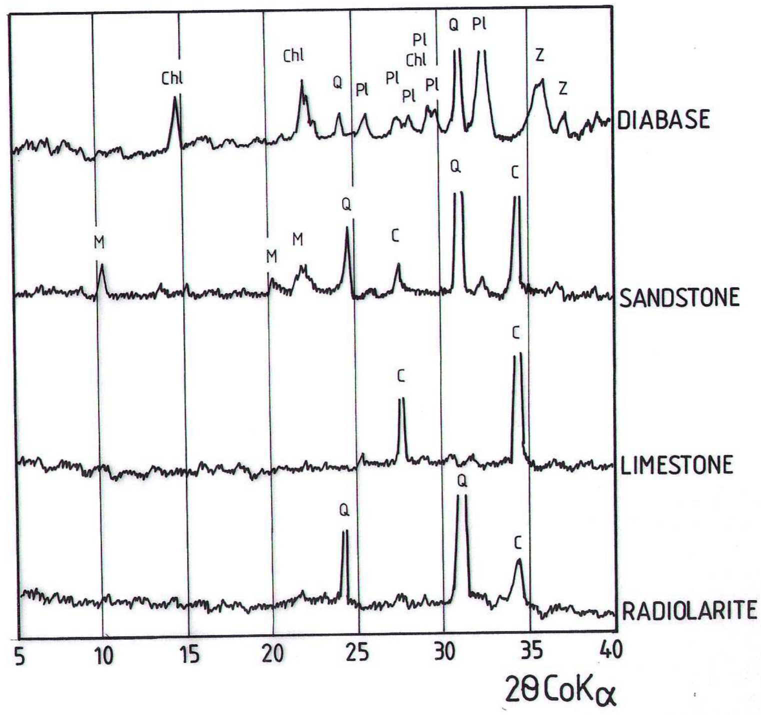


Fig. 5 X-ray patterns of selected rocks from natural outcrops near Leran Archaeological site.

Micaceous sandstone (sample XII),

The X-ray diffraction pattern confirmed the microscopic identification of the rock. The rock is composed of quartz calcite and muscovite. Traces of plagioclases were identified as accessory minerals.

Limestone (sample XIV),

The X-ray diffraction pattern (Fig. 5) has shown that this limestone is composed of pure calcite and does not contain more than 1.0 % of other minerals.

Radiolarite (sample IX),

The rock is composed mainly of quartz ($d_{\mathbf{hkl}}$ = 4.26, 3.34 A) and calcite was determined as the accessory mineral ($d_{\mathbf{hkl}}$ = 4.86, 3.34 A)

6. Comparison of stone implements from the Lerna site and rocks from natural outcrops.

1. **Determination of sources of stone implements from Lerna**

Examination of implements from the archaeological site and natural rocks collected during field survey showed the following correlation (Fig. 6) :

implements	**outcrop no**
a. diabase, serpenitinite, steatite, nephrite	outcrop 5c,
b. sandstones, siltstones	outcrops 2, 7,
c. siliceous rocks	outcrop 8 and region of Village Prosimna,
d. keratophyres, Cuores	outcrop 4b,
e. limestones	outcrops 1, 2, 3, 5a, b, 6a, b, c,
f. crystals of calcite	outcrops 5a, b,
g. phyllites	outcrops 2,
h. gabbro, microgabbro, serpentinized gabbro	outcrops 5c.

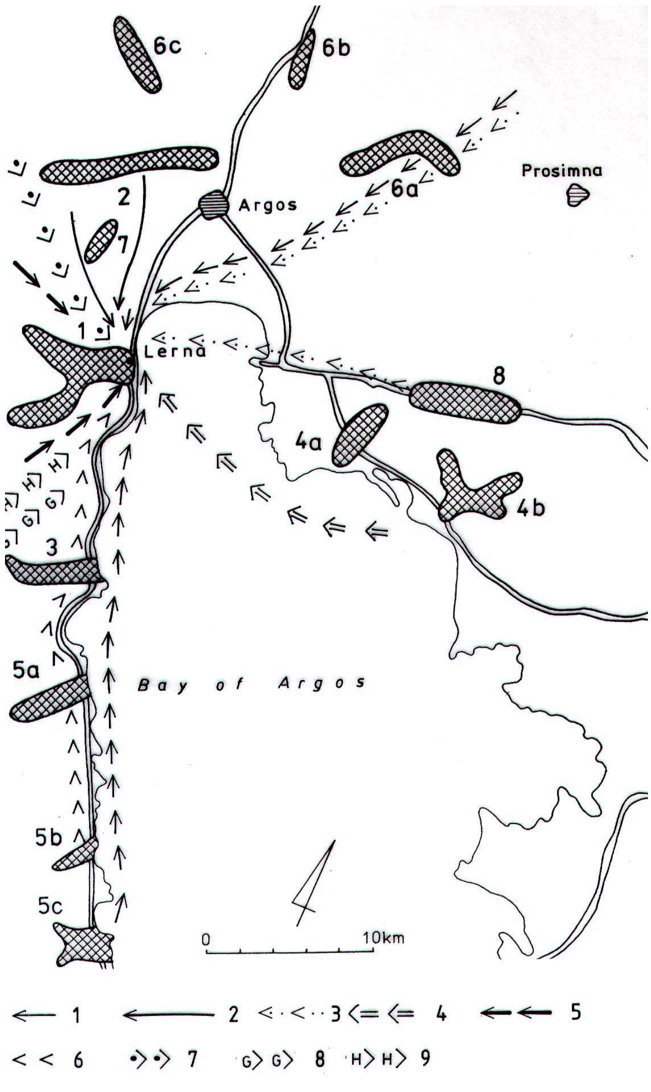


Fig. 6 Directions of the transport of various raw materials to the Lerna archaeological site during phases of the ocupation I-V. 1 diabase, 2 sandstones, siltstones, 3 siliceous rocks, 4 keratophyre, Cuores, 5 limestones, 6 calcite crystals, 7, phyllite, 8 gabbro, microgabbro, serpentinized gabbro, 9 hematite.

Stone implements found in the inventory of the Lerna site document various interest of the habitants in different stone raw materials in the period covering the Lerna IV phases.

The application of various raw materials is related to the manufacturing of different tools i.e. Purpose of the tool was a decisive factor in selection of a raw material that was to be employed for production of a tool.

Indirectly, it means that raw materials abundant in the stone inventory are proofs of changes in human activity. For example, serpentinites were used for production of axes and phyllites for production of small discs (distaffs). So the appearence of phyllite mainly in the Lerna V horizon inventory indicates the beginning of a usual activities i.e. spinning with the use of distaffs. It is significant to note that employing of various stony materials for the implements manufacture occurs in Neolithic and Bronze.

The main raw material used in Neolithic was obsidiane. Others like serpentinites and flints occur in the inventory of Lerna I and II horizons in small percentages. It means that the raw material was imported from a significant distance (above 100 km). The investigations showed that the stony material employed in Bronze (Lerna III, IV, V horizons) were brought to the site from a short distance, not exceeding 20-25 km.

Conclusions

The investigation documents the evolution of stone utilization during centuries of occupation of the site Lerna. Implements made of obsiadiane (from Melos) used at Neolithic phases later is completely substituted by other rocks and minerals. Rich and diversified sets of stone implements present at occupation phases I-V confirm the evolution of methods for the processing of rocks and minerals as well as a perfect and wide knowledge concerning sources, at times, located far away from the site. The stone raw materials were mostly local but some as for example, selected flints, are of unknown origin. Because of this, the presented investigation should be continued.

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Tables

Table 1

Mineral copmostion of rock implements from Lerna archaeological site (volumetric %). No of samples explained in text.

Mineral	Sample									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Quarts	5.7	9.2	37.0	50.0	31.7	-	-	28.1	39.7	15.2
Chalced.	4.5	4.5	-	-	-	-	-	-	-	-
Carbon.	-	-	28.8	29.7	51.8	100.0	100.0	-	8.0	65.8
Micas	-	-	6.6	1.9	5.6	-	-	1.0	-	4.2
Clay m.	-	-	-	-	-	-	-	-	-	12.1
Zoizit	64.2	71.2	-	-	-	-	-	48.9	-	-
Talk	-	-	-	-	-	-	-	-	-	-
Tr. - Act.	-	-	-	-	-	-	-	-	8.3	-
Opaque	1.4	7.5	1.1	2.0	-	-	-	3.1	11.7	2.7
K - Feld.	-	-	6.6	6.7	2.9	-	-	4.1	32.3	-
Plagio.	24.2	7.6	2.2	5.7	3.2	-	-	-	-	-
Pyrox.	-	-	-	-	-	-	-	2.4	-	-
Amphib.	-	-	-	-	-	-	-	10.4	-	-
Rock fr.	-	-	17.7	2.2	4.7	-	-	-	-	-
Glaukon.	-	-	-	2.0	-	-	-	-	-	-
Seladon.	-	-	-	-	-	-	-	2.2	-	-

Table 2

Results of grain size analyses of samples from the Lerna archaeological site (volumetric %).

Size	Sample									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0 - 5 μm	82.6	74.8	6.6	2.2	5.4	92.5	79.7	88.1	2.2	65.6
5 - 25 μm	17.4	23.0	30.1	44.6	85.9	7.5	20.3	11.8	67.1	33.2
25 - 50 μm	-	1.2	33.4	52.1	8.7	-	-	-	40.7	1.2
50 - 100 μm	-	-	23.3	1.1	-	-	-	-	-	-
100 - 200 μm	-	-	3.3	-	-	-	-	-	-	-
200 - 400 μm	-	-	3.3	-	-	-	-	-	-	-

Table 3

List of raw materials present at the area near the Lerna archaeological site (see map no 9)

Area	Main	Medium frequent	Minor
1. Lerna a, b	light limestones	green limestones hostones red, black sandstones siltstones silty limestone	marbles breccia
2. Valley located NW from Argos a, b, c	light limestones	phylllites organogenic limestones lithographic limestones sandstones siltstones silty limestones green limestones	hornstones red black breccia sandy limestone marbles
3. Astros a, b	light limestones	diabases serpentinites sandstones siltstones silty limestones bituminous limestones	hornstones breccia marbles
4. Area N and E from Tolo a, b	light limestones	keratophyric tuff keratophyres limestones green slilceous rock dibaase	chloritoides chalcedone quartz malachite Fe – ores agates red onyx black pumice jasper
5. a, b, c Lerna	diabase serpentinized	limestones microgabbro	hornstones calcite cryst.

Tiros	diabase and gabbro metamorphic slides serpentinite		talk, steatite hematite nephrite gnaiss
6. a, b, c Prosimna Fihti Shinohori	limestones of different colours	marbles	diabase chalcedone hornstones red, black
7. Near Kefalari	light – grey limestones claystones	sandstones siltstones slity limestone calcareous sandstone sandstone micaceous sandstone sand limestone	bitumineous limestones spherosiderite
8. Valley to the E from Naphlio a, b	limestones of different colours	diabases serpentinized diabases hortones sandstones claystones of. different colours	alcaline amorphic lavas grey flints cherts chalcedones hornstones

Table 4

List of the samples from natural outcrops tested mineralogically.

sample	**rock**	**region (of presence) no.**
I	black limestone	1
II	breccia	1
III	black hornstone	2
IV	steatite	5c
V	metamorphic slide	5c

VI	green serpentinite	5c
VII	grey flint	8
VIII	red flint	8
IX	red radiolarite	8
X	dark grey flint	8
XI	diabase	5c
XII	micaceous. sandstone	2
XIII	siltstone	2
XIV	limestone	1
XV	phyllite	2
XVI	marble	3
XVII	sandy limestone	2
XVIII	limestone	5a
XIX	claystone	7
XX	calcareous. sandstone	2

Table 5

Mineral composition of selected rocks from natural outcrops (volumetric %).

Mineral	**Sample**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Opal	-	-	-	-	-	-	-	-	-	-
Quartz	8.7	-	36.7	56.1	37.2	2.6	19.3	0.2	-	-
Chalc.	4.7	-	-	-	-	-	-	-	-	-
Carbon.	-	99.6	27.3	30.64	9.9	-	77.6	99.7	99.8	99.9
Micas	-	-	10.8	4.1	4.7	-	0.7	-	-	-
Clay m.	-	-	-	-	-	97.3	-	-	-	-
Zoizite	72.3	-	-	-	-	-	-	-	-	-
Talc	-	-	-	-	-	-	-	-	-	-
Tr. - Act.	-	-	-	-	-	-	-	-	-	-
Opague	6.1	0.4	0.9	0.2	3.1	0.1	0.2	0.1	0.2	0.2
F - Feld.	-	-	2.4	5.7	3.0	-	0.7	-	-	-
Plagio.	2.8	-	2.1	3.1	-	-	0.3	-	-	-
Pyrox.	-	-	-	-	-	-	-	-	-	-
Amphib.	5.4	-	-	-	-	-	-	-	-	-
Rock F.	-	-	19.8	0.2	2.1	-	1.2	-	-	-
Galauko.	-	-	0.9	-	-	-	-	-	-	-
Selad.	-	-	-	-	-	-	-	-	-	-

Chlor.	-	-	-	-	-	-	-	-	-	-

Table 6

Results of grain size analyses of samples from natural outcrops (volumetric %).

Size	**Sample**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0 - 5 µm	75.7	87.3	6.9	2.3	5.7	100.0	36.6	93.7	80.2	12.6
5 - 25 µm	22.8	3.0	30.2	12.8	84.6	-	12.8	6.3	19.8	-
25 - 50 µm	1.5	0.7	33.7	17.5	9.7	-	6.3	-	-	-
50 - 100 µm	-	0.1	23.0	35.6	-	-	10.0	-	-	-
100 - 200 µm	-	6.6	3.3	31.7	-	-	34.3	-	-	-
200 - 400 µm	-	2.3	2.9	-	-	-	-	-	-	-

Table 6 (cont.)

Size	**Sample**									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
0 - 5 µm	6.8	80.6	83.9	90.6	75.3	5.9	86.7	66.7	76.9	32.7
5 - 25 µm	83.6	4.2	11.4	8.7	24.7	84.3	12.3	32.6	12.8	47.9
25 - 50 µm	9.6	10.7	4.7	0.7	-	9.8	1.0	1.3	10.3	18.6
50 - 100 µm	-	4.5	-	-	-	-	-	-	-	0.8
100 - 200 µm	-	-	-	-	-	-	-	-	-	-
200 - 400 µm	-	-	-	-	-	-	-	-	-	-