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# STONE ARTEFACTS FOUND IN THE WESTERN DESERT OF IRAQ — THEIR SURFACE WEATHERING

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## Introduction

In the Western desert of Iraq (Badiat Ash Sham) extending from the depression of Ga'ara in the north, to the wadi Mira in the south, a considerable number of stone artefacts have been found (Mrázek, Petráček, 1981). An extensive production of stone instruments was very likely fostered, in the first place, by the natural supplies of workable silicious rock in the Western desert (fig. 1). Dating these artefacts presents a difficult task since they are not evident in any stratigraphical profile. The soft, slightly solidified types of soils and Quarternary sediments, indispesable for the stratification of the discoveries, had been, in this area, mostly removed by wind erosion. This is why all the artefacts are commonly found on the surface, and under shallow overhanging covers irrespective of their different ages.

For classifying stone artefacts, two entirely different methodical systems may be followed:

— according to their make, shape and age

— according to petrography, i. e. type of their mother-rock as characterized by modal and chemical composition, structure and weathering

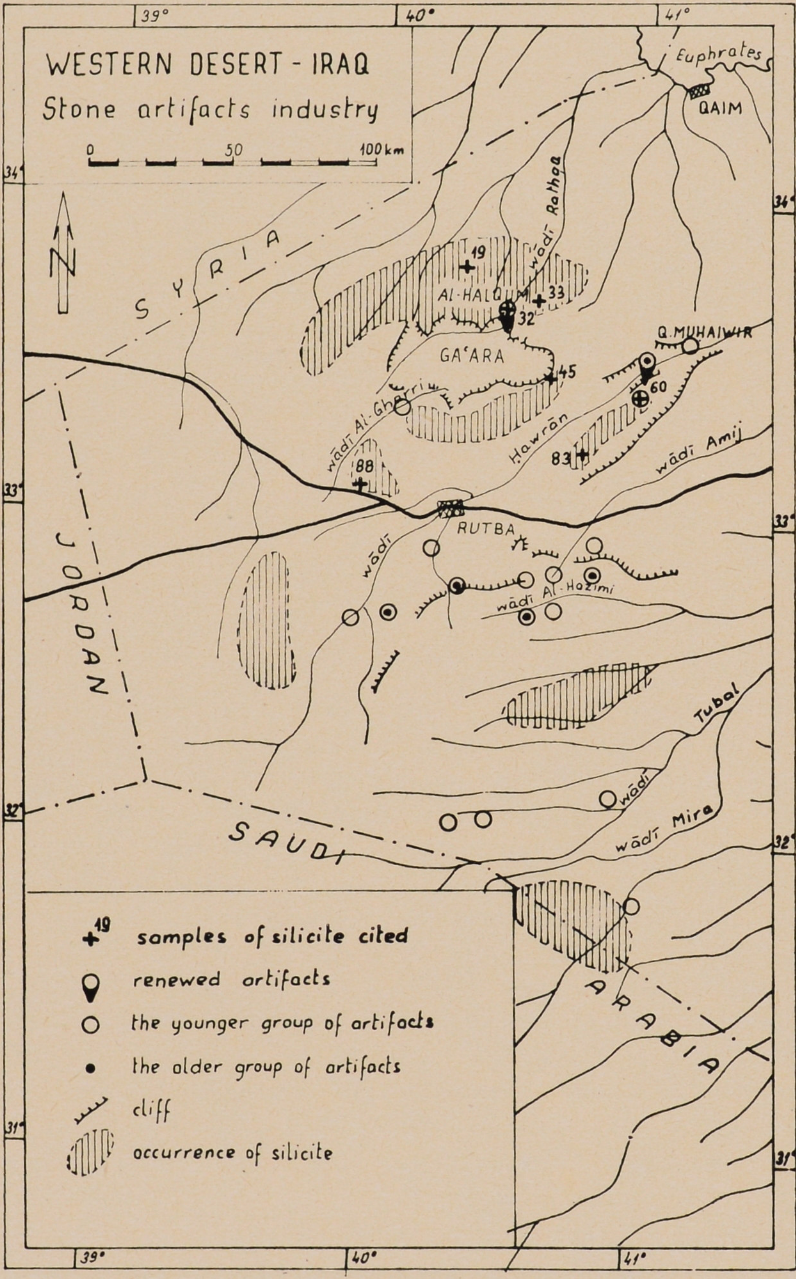

Fig. 1: Western desert — Iraq. Location of the stone industry and the raw material resource.

## Shape and age of artefacts

In comparing the shape of the artefacts found in the locality of Kilwa in Jordan (Rhotert, 1938), Jabrūd in Syria (Rust, 1950), Karim Shahr in Iraqi Kurdistan (Braidwood, 1951), etc., conclusion offers that in the Western desert of Iraq at least two groups of stone artefacts are represented.

The first group comprises hand axes, large splinters, and, very likely, also certain blades and axes (fig. 2, 3). Their shapes indicate affinity with Mousterian (Middle Palaeolithic). Naturally, the use of non-adapted pieces of stone as instruments should not be overlooked.

The second group of artefacts appears younger — points to a more recent date of production. It comprises various types of more or less geometrical instruments and microlites, mostly splinters, blades, cores, and refuse material. These artefacts were used as knives, borers, scarpers, arrow-points, and grinders, in many localities all over the area (fig. 4—8).

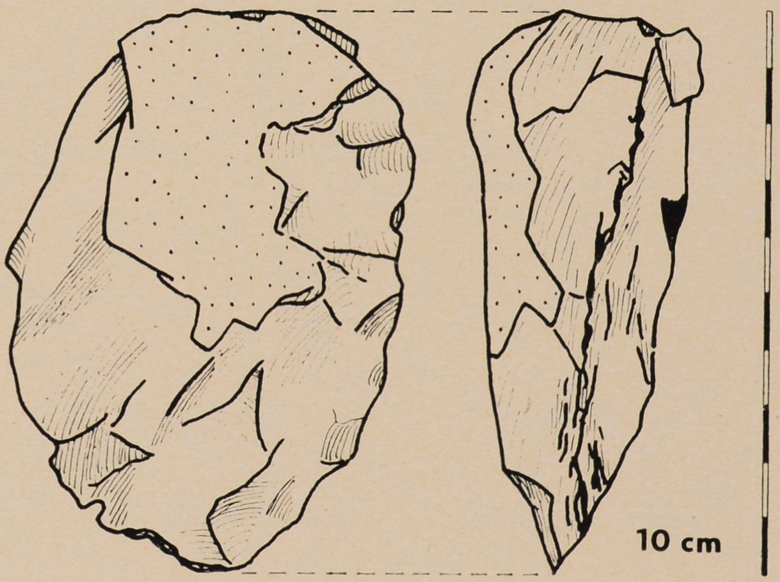

Fig. 2: Hand axe. The older group of artefacts. Vicinity of the wadi al-Hazimi. Brown dolomitic silicate, patinated. Natural surface dotted.

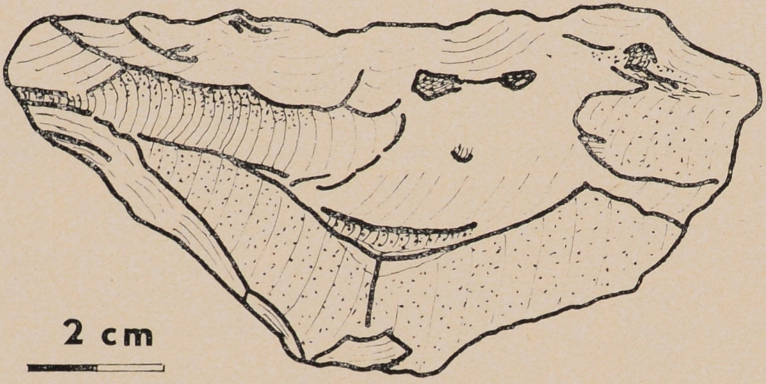

Fig. 3: Hard patinated flake. The older group of artefacts. Vicinity of the wadi Hawran, 90 km NE of Rutba. Brown dolomitic silicite. Dotted area — the limonitic crust.

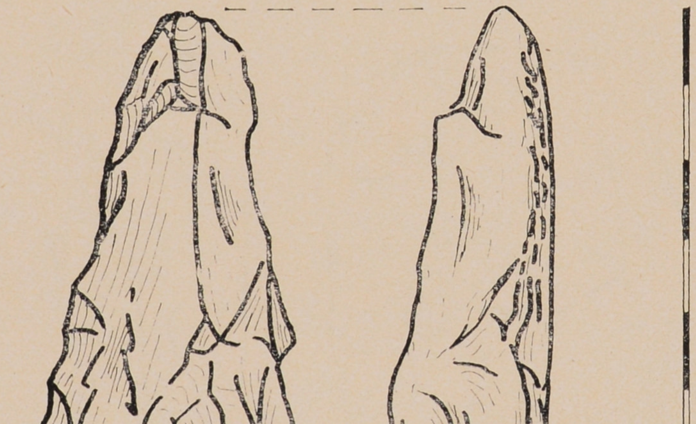

Fig. 4: Small axe. The younger group of artefacts. Brown dolomitic silicite without patina. Al-Halqum.

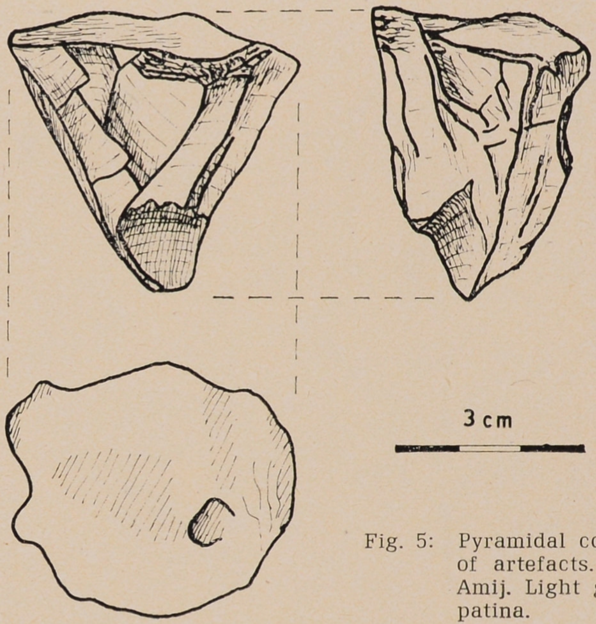

Fig. 5: Pyramidal core. The younger group of artefacts. Vicinity of the wadi Amij. Light grey silicite, thin light patina.

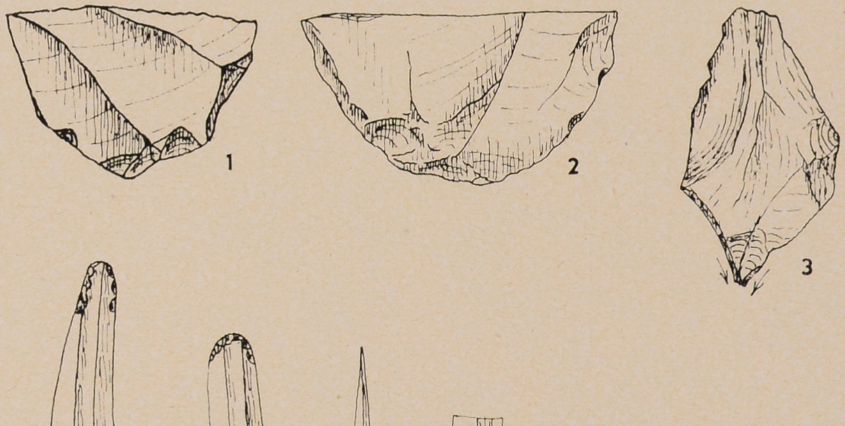

Fig. 6: Various artefacts of the younger group: 1, 2, — lunates, light brown silicite dark-patinated. 3 — flake with burin, brown silicite dark-patinated. 4, 5, 6, 7 — blades and one point, yellowish white porous silicite, weathered. All founds — Al-Halqum.

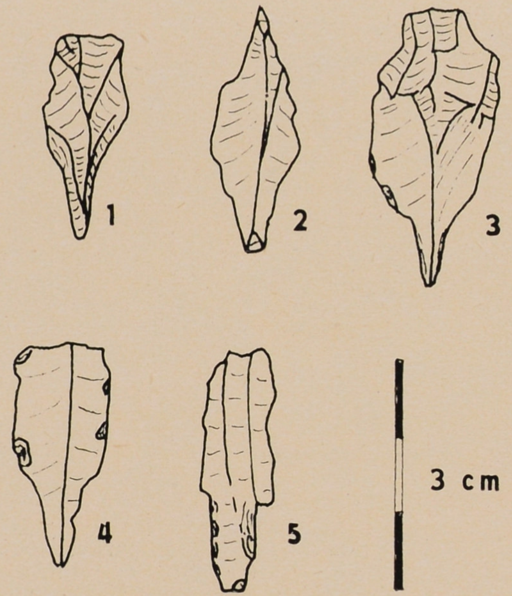

Fig. 7: Stemmed blades — arrow-points, some truncated. The younger group of artefacts. Al-Hazimi (1, 2), al-Gharri (3) and al-Halqum (4, 5).

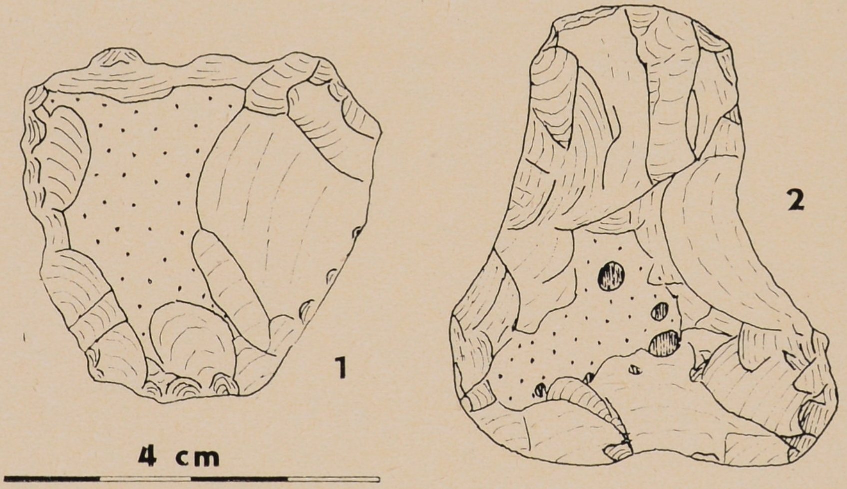

Fig. 8: Some tools of the younger group of artefacts. 1 — flake. Greyish-white silicite not patinated. Natural surface (pebble) dotted. Wadi Hawran area, 90 km NE of Rutba. 2 — axe. Light brown calcareous silicite, brown-patinated. Natural surface dotted. Wadi al-Gharri.

All these artefacts are very much like instruments found in other localities typical of the period without ceramics, and without obsidian instruments (the Kebara or Zarzien cultures in Iraq, Natūfien). The dating of this particular younger group of artefacts may be approximated between the Upper Palaeolithic and early Neolithic. These artefacts are usually discovered in proximity of certain rock engravings and stone enclosures/pens (as mentioned by Mrázek and Petráček, 1981).

## Composition of raw materials

The hard siliceous rock of which generally stone instruments are made — excepting vulcanic glass (obsidian) and siliceous sandstone — are currently called „flint“ or „chert“. A more accurate classification of their composition, texture, and weathering may be found helpful in solving certain archeological problems.

The composition and character of the raw material used for making stone instruments were newly determined by means of petrographical and mineralogical research, and chemical analyses — optical microscopic observation of thin polished sections. X-ray spectography, infra-red spectroscopy, and determination of contents of the principal elements.

The main component of the „flint“ and „chert“ is $SiO_2$, but the main chemical composition of the siliceous rocks is, in facts, greatly varied. They all contain a greater or smaller quantity of Ca, Mg, Al, Fe, Na, K, P, S, and of volatile elements. The rocks containing over 95 % of $SiO_2$ will be defined as silicites. All the remaining siliceous rocks will be designated according to their mineralogical composition, e. g., dolomitic silty silicite, silicified dolomite, etc. The transition from the pure silicite to the silicified rocks is very finely graded, relative to the rock genesis.

It is well known that the raw material suitable to making stone instruments is found in the entire geological profile of the Western desert, from Triassic to Palaeogene. In the carbonate sediments of the formation Mulusa, Ubaid, Digma, Tayarat, Umm ar Radhuma, and Dammam, there are many strata containing silicite concretions (Buday, Hak, 1980).

A number of instances showing the chemical composition of silicified rocks and silicites used for making artefacts are shown in Table 1.

The main mineral part of these rocks is quartz with its isometrical grains sized 1—5 $\mu$m forming a pavement structure. In certain instances, very fine radially-streaked ball-shaped aggregates of chalcedony are observed. Quartz was also determined by means of qualitative X-ray diffraction analysis.

Three macroscopically different samples of silicite were chasen for X-ray spectrographic analysis (Tab. 3). Guinier's focusing method as adapted by P. M. Wolff was used under the following conditions: CuK$\alpha$ radiation, 40 kV, 20 mA, period of exposition 8 hours. The resulting values d in Å were compared with literature values ASTM tables (Berry et al., 1974).

The presence of a low-temperature cristobalite as of one of the components of the opal matter in the rock was eliminated by means of the X-ray method.

| Sample | 45/1246 | 60/6262 | 83/6375 | 19/1388 | 33/1107 | 32/1323 |
|---|---|---|---|---|---|---|
| Formation | Mulusa | Ubaid | Ubaid | Dammam | Dammam | Umm ar-Radhuma |
| Age | Triassic | Triassic | Triassic | Paleog. | Paleog. | Paleog. |
| $SiO_2$ | 93.60 | 95.32 | 89.67 | 89.28 | 97.46 | 62.58 |
| $TiO_2$ | — | — | — | — | 0.03 | 0.06 |
| $Al_2O_3$ | 2.17 | 0.14 | 0.11 | 0.21 | 0.08 | 0.14 |
| $Fe_2O_3$ | 0.61 | 0.41 | 0.28 | 0.02 | 0.47 | 0.16 |
| MnO | 0.008 | 0.019 | 0.006 | — | 0.012 | 0.006 |
| MgO | 0.16 | 0.35 | 0.34 | 0.06 | 0.19 | 6.95 |
| CaO | 0.76 | 1.12 | 3.52 | 4.48 | 0.73 | 11.92 |
| $Na_2O$ | 0.17 | 0.04 | 0.02 | 0.22 | 0.06 | 0.16 |
| $K_2O$ | 0.95 | 0.06 | 0.01 | 0.01 | 0.06 | 0.05 |
| $P_2O_5$ | 0.03 | — | 0.06 | 0.09 | 0.09 | 0.26 |
| $SO_3$ | 0.46 | — | 0.39 | — | 0.24 | 0.46 |
| loss of ignition | 0.81 | 1.28 | 3.14 | 3.89 | 1.08 | 16.74 |
| Total % | 99.73 | 98.74 | 97.35 | 98.26 | 100.50 | 99.49 |

Tab. 1: Chemical analysis of some silicites from the Western desert — Iraq. Laboratory of State Organization for Minerals, Baghdad. Values in weigh per cent.

45/1246 : light grey silty silicite
60/6262 : greyish brown silicite
83/6375 : light grey calcareous silicite (silicified limestone)
19/1388 : light brown calcareous silicite
33/1107 : yellowish brown silicite
33/1323 : brown dolomitic silicite

Minerals of an identical chemical composition — $SiO_2$ — with different structures (quartz, cristobalite, and also the amorphous silica) may be identified by applying infra-red spectroscopy (Chester, Elderfield, 1968).

For quantitative determination of quartz and opal, weak absorption band may be used, with its peak near 695 $cm^{-1}$ (14.4 $\mu$), and also, or else, medium-intensity doubled vibration band at 795—770 $cm^{-1}$ (12.52 and 12.55 $\mu$) where an interference takes place between the bands of quartz and of opal. Since the quartz band at 695 $cm^{-1}$ fals in with vibrations of other minerals e. g. aragonite — 699 $cm^{-1}$, and kaolinite — 700 $cm^{-1}$, Chester and Green (1968) and Chester and Elderfield (1968) devised a method based on the intensity of the vibration double band at 795—770 $cm^{-1}$. The nature of this double band — with the presence of quartz and opal — is modified in the following manner:

1) in the relation quartz: opal is lower than 1 : 3, (i. e. opal in large quantity), the double band at 795 $cm^{-1}$ is not differentiated. This indicates the presence of opal while a weak vibration band at 695 $cm^{-1}$ declares a small quantity of quartz

2) if the relation quartz : opal is higher than 1 : 3 the double band at 795—770 $cm^{-1}$ is clearly indicated, the same as the vibration band at 695 $cm^{-1}$. The presence of opal in this case is difficult to prove; a special technique of infra-red spectroscopy is required.

The infra-red spectra of samples 33/1107 and 88/ — were acquired in the Institute of Geological Sciences, Charles University Prague, on spectrograph UR - 20 Zeiss, using prisms KBr in range 400—800 $cm^{-1}$ and NaCl in 800—1800 $cm^{-1}$. The method used pressed disc of 2 mg of sample mixed with 700 mg KBr. The samples were prepared in the usual manner.

The infra-red spectra are show in fig. 9. With regard to the foregoing explanation, it appears logical to presume that the sample 88/ — contains a considerably higher quantity of amorphous silica (opal) whereas the sample 33/1107 with a distinct absorption doublet contains a lesser quantity of amorphous silica if any. This is also shown in a larger content of loosely-bound water in the sample 88/ — which is direct relation to the ab sorption band at 1630 $cm^{-1}$.

| Sample | 45/1246 | 60/6262 | 83/6375 | 19/1388 | 33/1107 | 32/1323 |
|---|---|---|---|---|---|---|
| Formation | Mulusa | Ubaid | Ubaid | Dammam | Dammam | Umm ar-Radhuma |
| Age | Triassic | Triassic | Triassic | Triassic | Paleog. | Paleog. |
| Quartz<br>$SiO_2$ | 89.95 | 96.34 | 91.83 | 90.80 | 96.96 | 62.48 |
| Kaolinite<br>$SiAl_2O_5$ | 1.99 | — | 0.18 | 0.34 | 0.13 | — |
| K-felspar<br>$KAlSi_3O_8$ | 5.07 | 0.27 | — | — | — | 0.24 |
| Na-felspar<br>$NaAlSi_3O_3$ | — | 0.09 | — | — | — | 0.53 |
| Hematite<br>$Fe_2O_3$+Mn ox. | 0.62 | 0.47 | 0.31 | 0.03 | 0.50 | 0.18 |
| Magnesite<br>$MgCO_3$ | 0.34 | 0.75 | 0.72 | 0.12 | 0.39 | 14.63 |
| Calcite<br>$CaCO_3$ | 0.84 | 2.02 | 5.89 | 8.08 | 0.93 | 20.73 |
| Anhydrite<br>$CaSO_4$ | 0.68 | — | 0.68 | — | 0.41 | 0.68 |
| Phosphorite<br>$Ca(PO_3)_2$ | 0.003 | 0.03 | 0.10 | 0.13 | 0.13 | 0.37 |
| Halite<br>NaCl | 0.32 | 0.04 | 0.04 | 0.41 | 0.12 | 0.17 |
| Sylvine<br>KCl | 0.15 | — | 0.01 | 0.01 | 0.09 | — |
| rest of LOI like $H_2O$ | — | — | 0.22 | 0.08 | 0.34 | — |
| Total % | 99.96 | 100.01 | 99.98 | 100.00 | 100.00 | 100.01 |

Tab. 2: Normative composition of some silicites from the Western desert — Iraq. Values in weigh per cent.
For sample characteristic see Tab. 1.

Along with quartz, and, in sample 88/ — also alongside with opal, the silicites have revealed their contents of regularly dispersed scales of clay minerals, isolated rhomboeders of carbonates, phosphatized remainders of microfossils (mostly Foraminifera), and irregular diffuse smears of sulphates and iron oxides (Photo 1).

Optical microscopy of the very fine-grained siliceous rocks applies within very narrow limits. The picture of the contents of minerals in a rock can be supplemented with calculation of its normative composition. The data as quoted in Table 1 have been calculated for normative quartz, kaolinite, Na-K felspar, Fe-Mn oxides, CaMg carbonates, anhydrite, phosphorite, halite, and sylvine, while supplementing the losses of ignition as $CO_2$ and Cl. The unconsumed remainder of the volatile matters figures as $H_2O$. The unusually low remainder of the normative water, or else its absence, eliminates the existence of a substantial quantity of opal in the rock (Table 2).

The stone artefacts found in the Western desert were mostly made of local material. In isolated cases, the raw material or the actual products had been carried to a distance — not overreaching some 200 km — from the source of a suitable siliceous rock.

In several localities, a definite selection of materials as suited to making different instruments, can be detected. Certain small artefacts such as arrow-points and microlitic blades, are mostly made of a light grey to rusty brown translucent silicite with a slight content of silicates, carbonates, and phosphates. The coarser kind of instruments were usually made of a dark brown, less pure silicite, even silicified siltstone and silicified dolomite. Only a very few cases represent exception.

| Sample | 19/1388 | 33/1107 | 88/— | |
|---|---|---|---|---|
| d in Å | 4.26 | 4.26 | 4.26 | quartz |
| | 3.34 | 3.34 | 3.34 | quartz |
| | | | 2.880 | dolomite? |
| | 2.780 | 2.780 | 2.780 | quartz |
| | 2.455 | 2.455 | 2.455 | quartz |
| | 2.279 | 2.280 | 2.280 | quartz |
| | 2.233 | 2.235 | 2.235 | quartz |
| | 2.125 | 2.127 | 2.127 | quartz |
| | 1.977 | 1.979 | 1.979 | quartz |
| | 1.817 | 1.818 | 1.817 | quartz |
| | 1.671 | 1.671 | 1.671 | quartz |
| | 1.658 | 1.658 | 1.658 | quartz |
| | 1.607 | 1.607 | 1.607 | quartz |
| | 1.540 | 1.540 | 1.540 | quartz |
| | 1.452 | 1.452 | 1.452 | quartz |
| | 1.418 | 1.419 | 1.419 | quartz |
| | 1.382 | 1.382 | 1.382 | quartz |
| | 1.372 | 1.373 | 1.373 | quartz |

Tab. 3: Results of the X-ray diffraction analysis of silicites from the Western desert — Iraq. 19/1388: light brown calcareous silicite, 33/1107: yellowish brown silicite, 88/ — : light brown dolomitic silicite (quartz-opal geode).

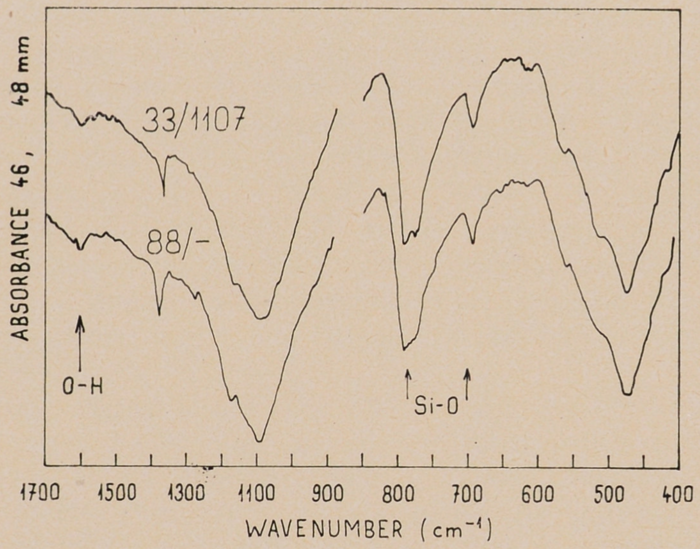

Fig. 9: Infrared spectra procedure illustrated for silicites from the Western desert — Iraq. 19/1388 : light brown calcareous silicite, 88/ — : light brown dolomitic silicite (quartz-opal geode).

A few splinters found in the neighbourhood of wadi Hawran and al-Hazimi, and one core found near the upper reaches of wadi Amij, are made of greyish-white, fine-grained quartzite. Quartzite forms thin layers in the so-called Rutba sandstone at the base of the formation M'sad (Cenoman — Upper Cretaceous). Quartzite surfaces at least 30 km north of the localities where discoveries were made — al-Hazimi and wadi Amij. Concerning the findings in the area of wadi Hawran, the material used might have been brought over from the river terrace.

In the wider surroundings of al-Hazimi, several grinders of various shapes and materials have been found. These semiglobular, roughly finished instruments are made of brown silicite (formation Digma, Turon). One particular fragment of a cylindrical, round-ended instrument is of red-yellow medium-grained sandstone (Rutba sandstone, Cenomanian). A similar shape is observed likely from the area where vulcanites are found — in Saudi Arabia south-west of Jabal Aneze. Not far from al-Halqum, a board-shaped grinder — 15 × 9 × 4 cm — was found, its under-plate polished off with use. Its material is slightly silicified organodetritic dolomite (lumachella), especially well suited to crushing grain with its coarse surface. In the entire area, mill-stones or fragments thereof made of porous blister basalt, were found. These had been used up to a very recent date. They are shaped as loaves with an opening in the middle for filling the grain in, and with an excentrically paced little hollow to hold the handle for turning the upper part of the „mill". The under-stone is somewhat thinner, and completely flat.

Near al-Hazimi were also found two stone ornaments bored through, made of the local silty dolomite.

## Weathering of artefact surface

On the natural surface of silicious rocks, and also on their artificial section planes, changes can be observed brought about in the course of the weathering processes — a patina. The surface of stone artefact found in the Western desert of Iraq shows traces of weathering. The nature of their patina depends on the character of their mother-rock, and also on outer factors of which the most important are rain water, and climatic conditions. The silicite section surfaces had been exposed to long-term effects of rainfalls that had modified them chemically, and, along with the effects of wind abrasion, also mechanically. The mechanical effects of water, and of the wind-propelled solid particles, are sufficiently well-known, but the chemical corrosion of minerals, and rocks, was not yet fully evaluated in archaelogy. Penetration of the rain water into the surface of the artefacts is at times facilitated through microscopic peeling joints, the effect of the inner tension of the rock in the course of considerable changes in temperature (Photo 2).

Chemical weathering of silicites and of similar rocks in the Western desert of Iraq resulted in the following phenomena:

— light patina and weathering crust

— surface corrosion without originating patina

— dark lustrous patina (desert varnish)

### *Origins of light patina and weathering crust*

A light-coloured surface is seen mostly on artefacts made of silicites, containing a higher portion of carbonates, phosphates and sulphates. These easily dissolving minerals are leached out by rain water. Under protracted action water may also corrode the edges of quartz grains. With regard to the high concentration of carbonate ions in the intergranular solution, Fe compounds are relatively stable, and remain regularly dispersed in the rock. In this way, a light-coloured porous crust appears of which the thickness depends on the mineralogical composition of the rock structure, on the quantity of water leaching the rock, and on the duration of the weathering process (Photo 3). On the natural surface, the thickness of this crust varies from 3 to 6 mm, on an artificial section surface from 0.01 to 2 mm. Its formation is not limited by climatic conditions while naturally in areas with higher humidity, a more rapid development may be expected.

Certain microlites are, in this way, weathered throughout, without any darker rock conserved in the cores of the artefacts. The original shape, dimensions, and sculpture of the artefact were conserved unchanged while only the material weight of silicite was reduced.

The light weathering crust easily absorbs water and other liquids, and grows somewhat darker approximately within 48 hours. This change is reversed following the drying-out of the sample. In certain cases, following even a longer period of immersion into the fluid, a network of lighter-coloured lines remains visible on the surface of the sample. The lines indicate the course of the desiccation joints, originated in the altered volume of the rock owing to the dehydration of the siliceous gel in the course of diagenesis (Photo 4). These joints obviously are not effected by weathering.

In the silicites lacking any considerable component part of easily soluble minerals, a conspicuous light-coloured porous crust does not form. In rarer cases, a thin white or light-grey patina appears on the natural surface of this kind of silicite after its long exposure to the effects of weathering.

*Corrosion of artefacts without appearance of patina*

In some period of high humidity, dissolution of the silicite, and washing-away of the silica in the solution, might have occurred. The dissolution of $SiO_2$ in water is illustrated in fig. 10. With a higher alkalinity of the solution (higher than pH 9), the solubility of all the modifications of $SiO_2$ steadily increases. The velocity of the solving process of quartz is in direct relation to the dimensions of the interfacial area, in consequence of which follows: The finer-grained the silicious rock, the larger quantity of $SiO_2$ is received into the solution (fig. 11).

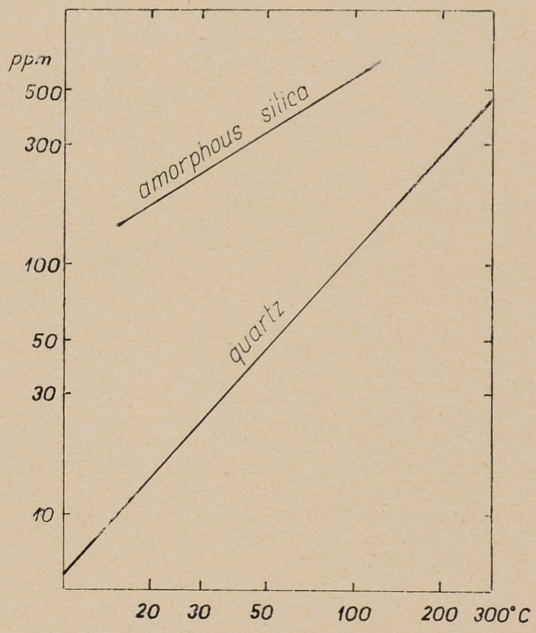

Fig. 10: Solubility of quartz and of amorphous $SiO_2$ (R. M. Siever, 1962)

The solving process of quartz may be found accelerated by destabilization of the crystalochemical structure through aeolian abrasion of the silicite surface, or cosmic radiation (fission tracks). Gordon and Harris (1955, 1956) in the course of their X-ray research of different-sized fractions of quartz established intensity diversions of the reflections caused by a surface layer of amorphous silica. This layer originated in a mechanical rubbing of the grains while the samples were being crushed.

During the phases of X-ray studies, attention was paid to the eventuality of this thin layer of amorphous silica appearing on the surface of stone artefacts found in the Western desert of Iraq.

In order to remove the eventual amorphous layer, the sample with the natural surface No. 19/1388 was exposed to the ac-

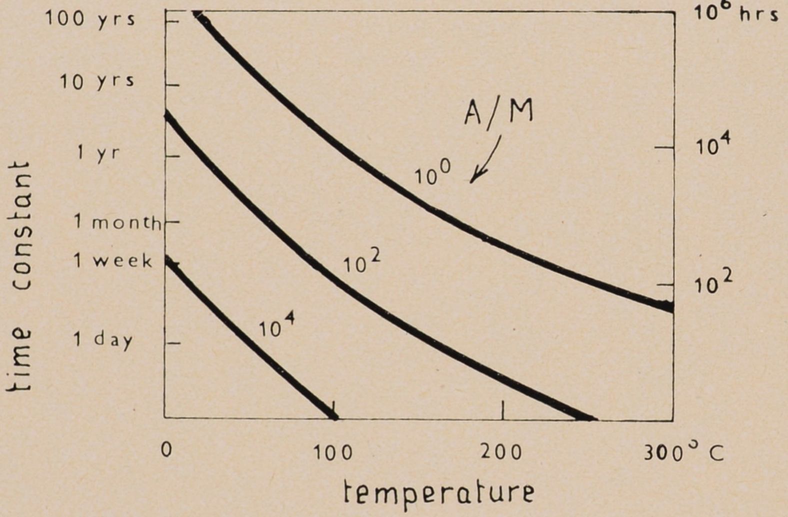

Fig. 11: Time constants for the reaction $SiO_2$ with $H_2O$. Index (A/M) indicates the extent of the system: A is the interfacial area in m$^2$, M is the amount of water in kg. The diagram shows the following conclusion: the larger the area of the reaction of the two components of the system, the more rapidly is established an equilibrium between the solid phase of $SiO_2$ and $H_4SiO_4$ solution (according to J. M. Rimstidt and H. L. Barnes, 1980).

tion of HF for the period of two hours. The results of the phase X-ray analysis of samples attacked and samples not attacked, with natural surface, were compared (fig. 12). X-ray analysis was carried out on a difractograph Müller Micro 111, X-ray radiation $C_0K\alpha$, 40 kV, 18mA, velocity of movement of goniometer 1° × min.$^{-1}$, paper shifting 40 ×, sensibility 2 × $10^3$, background 0. The results of the comparative measuring clearly show that following an attack of the samples by HF for a period of two hours, the intensity of the quartz reflection did not change.

### *Origin of the dark patina*

The natural surface of silicites and the surface of some of the artefacts found in the Western desert of Iraq is, in many cases, lustrous, rust-coloured, or even black-brown in hue (the so-called desert varnish). On polished sections, this dark patina appears as a very thin overall, even, uninterrupted covering. No trace of increased porosity was noticed (Photo 5).

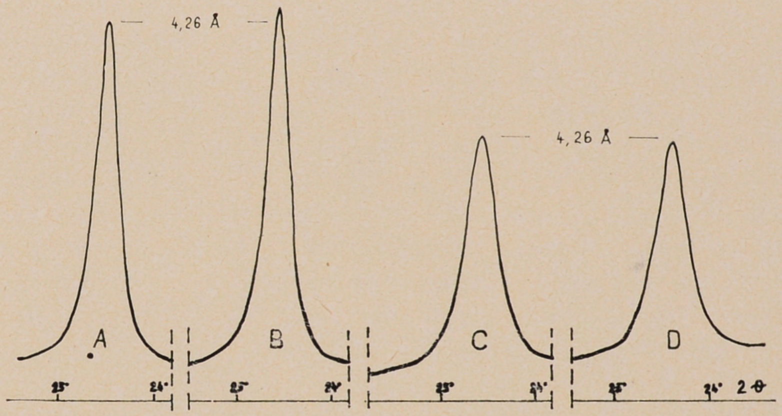

Fig. 12: Reflection of the structural plane of quartz (100)—4.26 Å.
A — sample 19/1388 of which the surface was attacked by HF.
B — the same sample with natural surface.
C — sample 88/ — of which the surface was attacked by HF.
D — the same sample with natural surface.

The dark desert varnish on the surface of silicite differs in appearance, thickness and structure from the dark crust as seen on the surface of siliceous sandstone, granite, basalt, and some other rocks. The two kinds of patina probably also differ in their respective genesis. The dark crust on the surface of medium-grained-to coarse-grained rocks with a relatively high porosity is caused by an output of iron from the inside bulk of the rock, with its solutions rising to its surface (also K. Willmann in Rhotert, 1938). This process is conditioned by a higher evaporation rate of water than the rate of condensation, and absence of carbonates in the rock.

The silicites have a very low porosity. The migration of solutions can be proved only down to a few milimetres under their surface along with the formation of a light-coloured weathering crust; or else, their migration cannot be proved at all.

The mineralogical composition of the desert varnish on the surface of artefacts found in the Negev desert in Palestine was studied by Potter and Rossman (1979 a, b) with the method of infra-red spectrometry. The prevailing mineral is birnessite (Mn-oxide). The presence of kaolinite and hematite was also established, and, in a smaller measure, minerals of the illite-montmorillonite group, and quartz.

The origin of this kind of patina can be explained as a periodical interaction of rock and condensation water in arid climatic conditions. The periodical contact of condensation water (dew, light shower) with the rock only lasts a few minutes or hours. Nevertheless, a slight dissolving of quartz takes place. Some solution of $H_4SiO_4$, and also, residual aeolian, and hard-soluble solid particles (especially clay materials) stick to the uneven places on the rock surface, and are not entirely and continually rinsed away as is the case in humid areas. After its condensation water evaporates. Results coagulation of $H_4SiO_4$ while a continuous layer of clay particles cemented with silica, forms. An alteration of these processes may be, within every year, repeated many times over. In exogenous conditions there exists little probability of a new formation of alumosilica gels and clay minerals.

The thin layer of clay minerals and of amorphous $SiO_2$ on the surface of silicite is capable of absorbing ions $Mn^{2+}$ and $Fe^{2+}$, released from the dissolved silt particles. Iron and mangan were fixed on the silicite surface by their oxidation along with the formation of birnessite.

As experimentation has proved, the un-weathered silicite also has a capacity of binding heavy metals.

Two samples were used for our experiments:

33/1107 — light brown silicite with dark lustrous patina

88/— — semi-transparent silicite with a suggestion of light-coloured patina

After the removal of natural surfacing, the samples were homogenized. By sieving, fraction 50 to 200 $\mu$m was prepared. Samples of 4 g were mixed with $3 \times 10^{-4}$ M solution of $CuSO_4$, and left for 24 hours. Following filtration of the solution, the residual concentration of free $Cu^{2+}$ ions was measured electrochemicaly. Apparatus used was PHM 62, Cu electrode F 1112 and combined reference kalomel-electrode of the Radiometer-Copenhagen production. With both samples a complete removal of free ions $Cu^{2+}$ was proved from the solution, and also altered concentration of hydrogen ions from the original pH 5.0 to 7.5 after the completion of the experiment. Apart from the absorption of ions, an eventual bond of Cu with an infinitesimal admixture of carbonates and phosphates in the rock cannot be eliminated.

## Weathering of artefacts and determination of their age

It was Winkler in 1938 who pointed out difficulties accompanying the determination of the age of archeological objects with the aid of the thickness of the weathering crust, and patina. It is now known that in the last 18—20 thousand years, the condensation rates increased several times, and conditions influencing the development of patina, kept changing. This is the reason why in the Western desert of Iraq the thickness of the weathering crust and patina on the artefacts cannot yield a reliable basis for the calculation of the period of time during which the artefact had been exposed to weathering. Nevertheless it is possible to state that the older group of artefacts mostly show a conspicuous dark brown to rust-coloured lustrous patina with islets of limonitic or calcareous crust, whereas the patina on the younger artefacts is hardly noticeable. The thick patina seen on the older artefacts was formed very likely during the very dry post-pluvial period (26—14 thousand years BC). The variations in the thickness of the light-coloured weathering crust are for too extensively influenced by the petrographical composition of the rock, and consequently, cannot serve the purpose of dating the artefacts.

In certain stone artefacts, even the loss of their weight only might be taken as a basis for establishing their age.

The reactions of rock to water are not very rapid (fig. 10). As Garrels pointed out (1959), in certain cases the speed of the reaction may be more important than the balanced conditions between the rocks and the chemically active solutions. In consequence the volume of the dissolved $SiO_2$ in natural waters is relatively constant. Davis (1964) has established the fact that the median of the $SiO_2$ content in ground waters in the USA is 17 ppm (tolerance 7—43 ppm), and in streams 14 ppm. The volumes of $SiO_2$ in natural waters are influenced neither by climatic conditions, nor by pH of the water, vegetation, nor by the concentration of the other ions. But they rise as much as 50 % in the warm waters of the tropics (25—30 °C) as compared with the arctic waters (0—5 °C). They depend, in the first place, on the water-rock interaction. The highest volume of the dissolved $SiO_2$ is found in the natural waters contacting volcanites, a smaller amount is leached from plutonites and marine sandstones, and, the smallest volume of water is leached from carbonaceous rocks. The amount of $SiO_2$ carried away in solution from a drained area by streams, is in direct relation to the movement velocity of ground water. In the climatic conditions of the USA, it varies from 0,01 mg $\times$ $cm^{-2}$ $year^{-1}$ in the deserts, to 2,0 mg $\times$ $cm^{-2}$ $year^{-1}$ in humid mountainnous regions (Davis, 1964). These values are naturaly relative not only to the solubility of quartz and other modifications (silica), but mainly to the releasing of $SiO_2$ from the silicates.

In the arid climate, some portion of the $SiO_2$ is carried away by wind. The degree of rock surface aeolization can fairly be determined by way of optical study. In the area of the Western desert of Iraq, aeolization is noticeable in the first place on soft carbonaceous rocks and calcareous sandstones. Aeolian abrasion of the hard siliceous rocks can be observed, only in places, on the natural surface, i. e. on certain pebbles in terrace material near the wadi Hawran. Judging from the good condition of the weathering crust or of the dark patina covering the surface of the artefacts, the effect of aeolian abrasion on those under observation is considered negligible.

Thus the loss of 0,01 mg $SiO_2$ $\times cm^{-2}$ $year^{-1}$ as given by Davis (1964) for the desert areas of the USA, can be accepted for the Western desert of Iraq the more readily since also the geological conditions and mineralogical composition of the rocks are like in the two areas. The accepted value relates to the decrease of a quartz layer thickness of $3,85 \times 10^{-5}$ mm in one year. The calculation of the thickness of the layer removed from the surface of the silicite in relation to time is expressed in fig. 13. The values quoted should be minimal. Any eventual variations in the quantity of $SiO_2$ carried away during a period of increased humidity, may only be positive.

Considering the degree of conservation, the majority of artefacts found in the Western desert of Iraq do not appear to be older than 20,000 years. To reach more accurate conclusions, a special detailed study of the shapes and surfaces of the artefacts on the location of their discovery would be required, along with the hydrological and paleontological research of the area under study.

In two localities, namely, al-Halqum, and the wadi Ubaid — 20 km W of Qasr Muhaiwir — a number of patinated artefacts were discovered belonging to the younger group, which had a renewed retouche on their edges, broken points, and, in one case, little depressions made by shock on their bulbar side (Photos 6 and 7). The newly fractured planes cut accross the light-coloured porous crust on the old planes of the blades, and reveal the fresh rock inside the object. The thickness of the crust is 0,5—1,0 mm. The new planes are not patinated. This fact offers evidence of a third — the youngest — phase of using stone artefacts in the Western desert of Iraq. It is not impossible to conclude that the Paleolithic and Neolithic instruments, found by chance, might have been used in emergency and adapted by some people up to recent times.

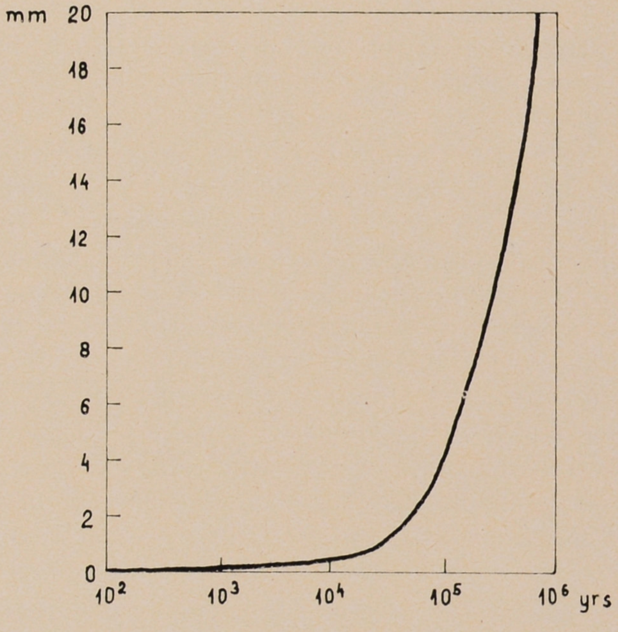

Fig. 13: Plot map of $SiO_2$ removal in mm of thickness and time (according to Davis' results in 1964, for desert conditions -0,01 mg $SiO_2 \times cm^{-2} \times yr^{-1}$).

Stone artefacts may be found almost in the whole vicinity of Ga'ara depression and al-Wudian, but the newly-retouched objects appear only in two — the relatively most humid — places of the entire area. At the entrance of the wadi Ratqa, draining the Ga'ara depresion, and near the wadi Hawran, draining a vast river basin extended right down to the boundaries of Saudi Arabia, the ground water level even in a very dry period, is close to the surface. Conclusion follows, that the most recent use and adaptation of the Neolithic instruments took place in the last period of desertification of the area under study, i. e., after the Atlantic (after 3,000 BC), or even after the Palmyrian period — at the beginning of our age.

## Conclusion

1) In the Western desert of Iraq, stone artefacts of different ages have been found. They furnish evidence of favourable conditions having existed to foster the development of the paleolithic and early neolithic human communities in this area.

2) Raw materials used for making these artefacts were solely the local rocks, mostly dolomitic silicite in which the main component is quartz.

3) The surface of the artefacts, in the course of weathering, got patinated. The formation of the light-coloured porous crust was conditioned by a higher volume of carbonates and other easily soluble minerals contained in silicite, removed by condensation water. The formation of the dark patina is conditioned by frequent alterations of condensation and evaporation of water in the arid climate. The thin layer of residual clay minerals cemented by a newly-formed siliceous matter, as well as the silicite, absorb ions of iron and manganese.

4) Neither the thickness of the weathering crust nor the dark patina offer a reliable basis for estimating the age of stone artefacts. But the fact is that the group of the older stone artefacts show a more conspicuous dark patina than the younger group.

5) The decrease in the weight of the artefact is in relation to the duration of chemical corrosion and mechanical abrasion of its surface. Under certain conditions, the loss of weight of the artefact may be considered in approximating its age.

6) Some of the discovered artefacts show traces of subsequent-more recent adaptation of form effected on their surface after the formation of the light-coloured weathering crust. This proves more recent use of instruments produced earlier.

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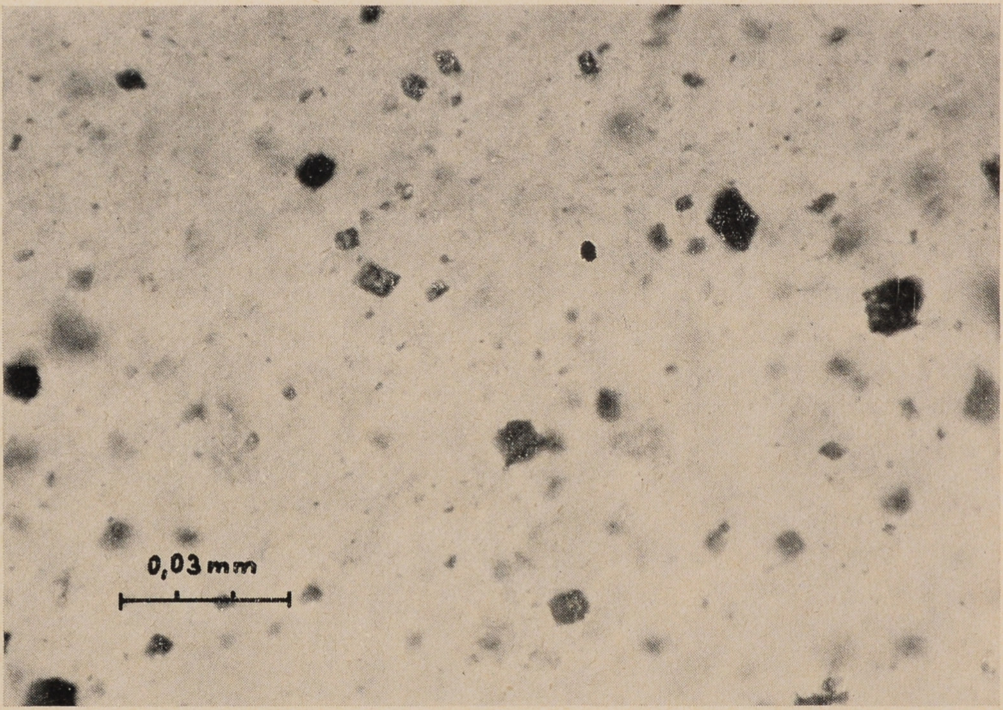
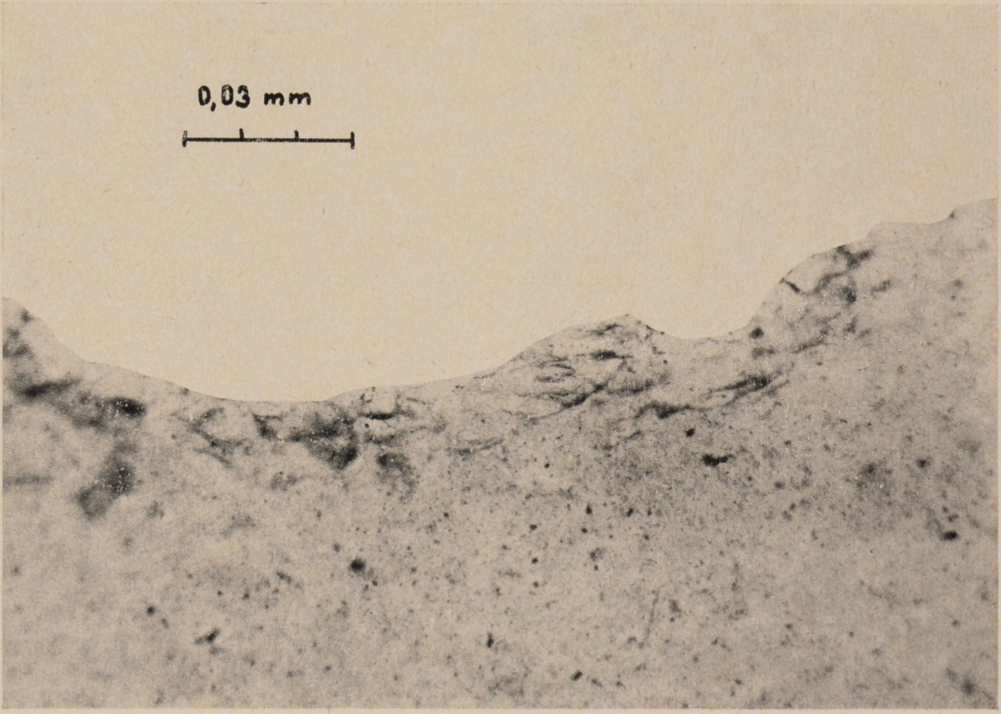
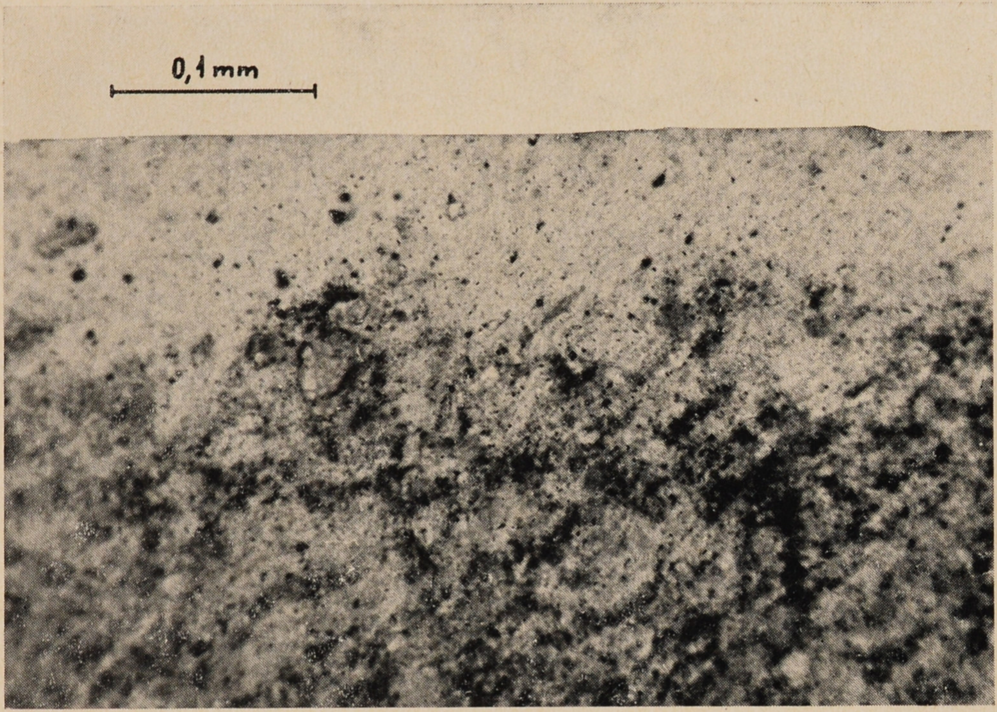


1 Dolomitic silicite. Dark regular grains — dolomite. Thin section.

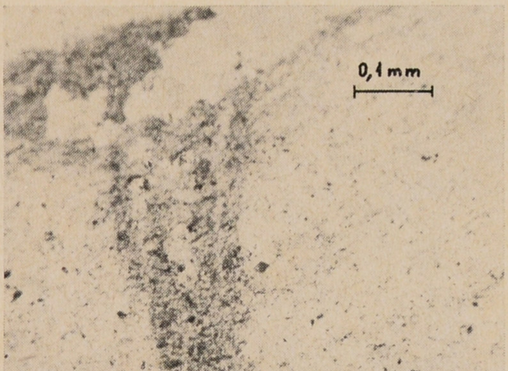
2 Peeling joints near the artefact surface. Calcareous silicite. Thin section.

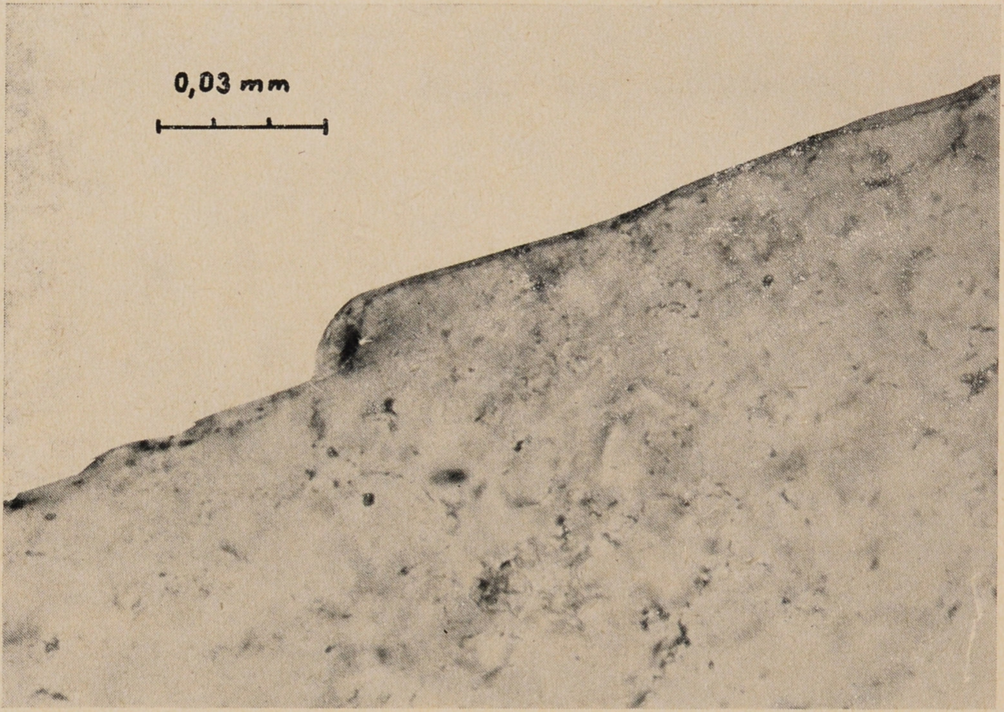




3 Light porous weathering crust on the surface of calcareous silicite. Thin section.

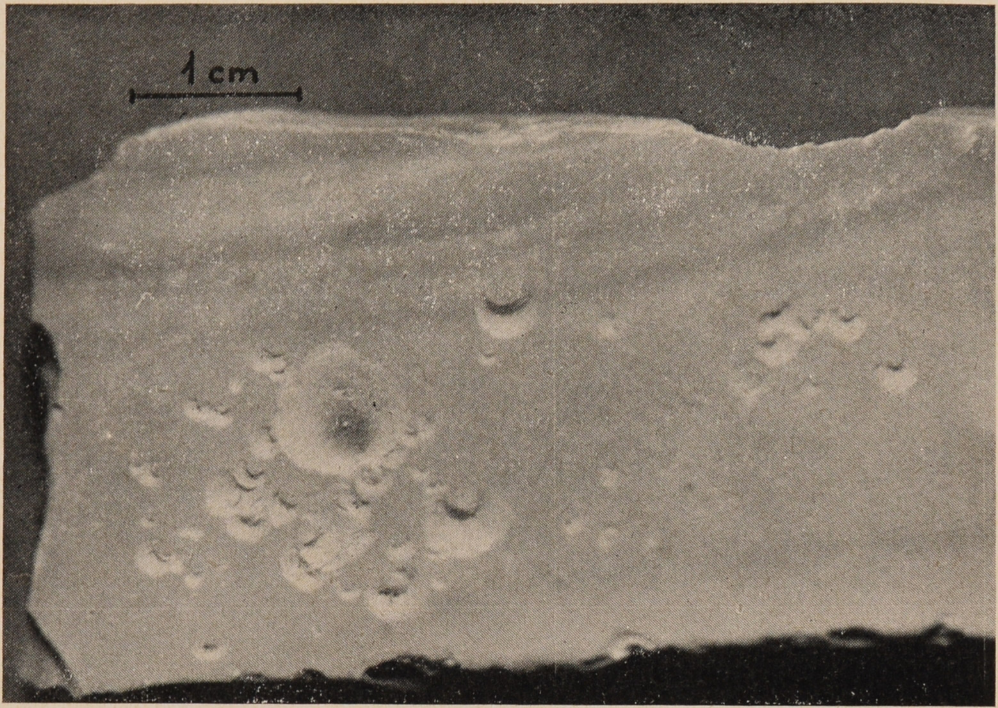
4 Desiccation joint. Calcareous silicite. Thin section.





5 Dark patina (desert varnish) on the surface of silicite. Thin section.

6 The renewed retouche on the edge and truncated point of the blade. Al-Halqum.



7 The shock hollows on the bulbar side of the blade. Al-Halqum.