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ETCHING OF MOLDAVITES UNDER NATURAL CONDITIONS

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16. Abstract The paper advances the hypothesis that a part of the lechatelierites which originated by etching from a basic moldavite mass became broken off after deposition of moldavite in the sedimentation layer. Those found close to the original moldavite were measured for statistical averaging of length.

The average length of lechatelierite fibers per cubic mm of moldavite mass volume was determined by measurement under a microscope in toluene. The data were used to calculate the depth of the moldavite layer that had to be etched to produce the corresponding amount of lechatelierite fragments. The calculations from five "fields" of moldavite surface, where layers of fixed lechatelierite fragments were preserved, produced values of 2.0, 3.1, 3.5, 3.9 and 4.5.

Due to inadvertent loss of some fragments the determined values are somewhat lower than those found in references. The difference may be explained by the fact that the depth of the layer is only that caused by etching after moldavite deposition.

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In comparison to tektites that are relatively young (such as e.g., australites and tektites of southeastern Asia), in which their original surface became well preserved under favorable conditions (O'Keefe 1967), in the case of old tektites--among which we may include moldavites--determination of their original shape and dimensions which they had upon impact on the surface of the Earth is very difficult. /140*

During the course of millions of years such tektites underwent, on the one hand, a more or less extensive transport and the resultant abrasion, while, on the other hand, they were obviously exposed to the effects of weathering and etching the extent of which can be determined only with difficulty.

Effects of etching were already pointed out by Jezek (1911) and Rosicky (1939) in connection with the problem of the origins of sculpturing.

On the basis of optical properties of moldavite from Locenice detected during observation in polarized light, Rost (1967) reached the conclusion that loss of surface layers due to corrosion ranges between 3-6 mm.

New findings relevant to the problem of etching resulted from laboratory experiments of Kellner and Huang (1971) who studied extractive dissolution of individual elements from the surface layers of masses of moldavite and of obsidian for a period of 21 days.

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*Numbers in the margin indicate pagination in the foreign text.

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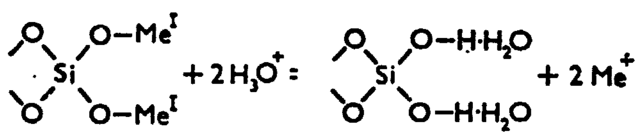
The results of the study made by Keller and Huang in regards to etching of natural glasses (1971) essentially coincide with a personal communication by Vojtech regarding his experimental results obtained in dissolution of synthetic and natural glasses, as well as with the concept regarding the mechanism of damage caused to glass by aquous media (Weyl 1938, Hlavacova 1964, Kaller 1957, Keppeler 1934, Berger 1936).

According to these concepts, the formation of glass is participated in, on the one hand, by a solid bond between silicon and oxygen atoms Si-O-Si which forms the basic tetrahedral unit of ions SiO_4- in the glass structure and, on the other hand, by the relatively weak bond of Si-O-Me (Me representing an atom of metal). This applies particularly in a case involving a bond between this anion and a univalent cation.

Damage to this weaker bond occurs in the presence of water or diluted acids on the surface of glass primarily due to the effects of hydrogen (eventually hydroxonium) ions during formation of a layer of a gel of silicic acid according to the formula



During elutriating of hydroxides in the course of etching the thickness of the gel layer increases with time, unless there occurs a mechanical removal of the layer. The speed with which this layer is formed is limited by diffusion of water through this gel and it is only of an approximately parabolic character (Keppeler 1934, Berger 1936). For this reason it is difficult to extrapolate the results of relatively short-term laboratory experiments to a period covering millions of years.

The described reaction does not occur in the case of silica glass in which the bond between silicon and metal is absent (Kaller 1957); thus silica glass, which is contained in moldavites in the form of lechatelierite grains and fibers, is more resistant against the effects of neutral and acid solutions. Under natural conditions the chemical resistance of lechatelierite is additionally enhanced by its favorable mechanical properties.

Therefore, a direct proof of surface layer losses could be con- /141 stituted by the length of lechatelierite protrusions on moldavites which in view of the specified properties became retained after the occurrence of basic mass etching.

It is hard to assume that lechatelierites, which are found on the surface of some moldavites and are often of a thickness of only several thousandths of a mm, could have survived their impact on the terrestrial surface and, consequently, had to be formed by etching of the basic substance. On the other hand, it is easy to assume that the protrusions which were formed by etching could have become broken off after reaching a certain length in the sedimental layer, be it in the course of millions of years or during removal from the sediment yielding moldavites. In the latter case it can be expected that lechatelierite fragments will be found in close proximity of moldavites. To verify this contention we examined some moldavite layers in the sand deposits southeast of Vrabec which we considered suitable for these purposes due to, among other reasons, their age (Bouska 1964). We accumulated a substantial number of lechatelierite fragments during the 1978 season.

At this occasion we found a moldavite--now inventory number 354 in private collection--(dimensions 25x17x8 mm, weight 2.25 g) that could be removed with at least a partially undamaged layer in which remained imbedded broken-off lechatelierites. The contributory circumstance was the fact that the sand and clay layer was permeated by ferrous compounds that helped to fixate the fragments.

Experimental Part

a) Acquisition of Loose Lechatelierite Fragments

Sand from the immediate vicinity of the found moldavites was elutriated. The finest part of clayey particles was decanted. Larger particles were removed by mechanical methods and the remaining finer residue was evaporated. Lechatelierite fragments were removed from this fraction mechanically under a microscope.

b) Counting and Measuring of Lechatelierite Fragments on the Surface of Moldavite and Determination of the Overall Length of Lechatelierite Fibers in Moldavite

Lechatelierite fragments in the individual fields of moldavite no. 354 were added up under a microscope. Data regarding the number of fragments in individual fields are shown in Table 1.

TABLE 1.

1	2	3	4	5	6
Pole	Počet lecha-telieritů	Plocha v mm^2	Počet ks na mm^2	Sumární délka na mm^3	Odlep-táno mm
A	211	26,8	7,9	2,8	4,5
B	28	5,4	6,7	1,9	3,1
C	18	2,7	6.1 ~~5,2~~	2,4	3,9
D	13	2,9	4,5	1,6	2,6
E	26	4,3	6,0	2,2	3,5
				Average	3.5

Key to column headings: 1 - Field; 2 - Number of lechtelierites; 3 - Area in sq mm; 4 - number of pieces per sq mm; 5 - Summary length per cubic mm; 6 - mm etched off.

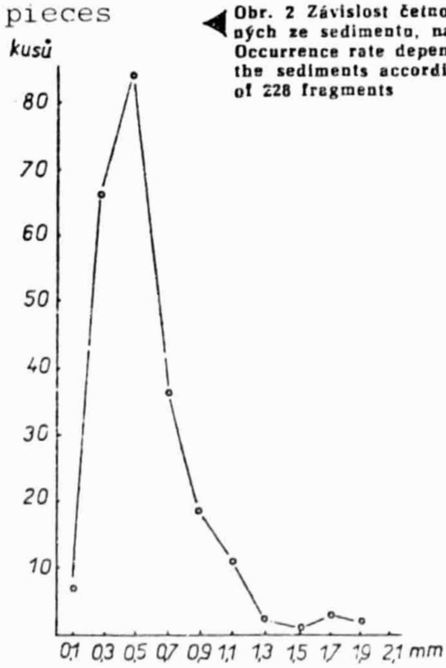
At the same time was measured the length of individual lechatelierite fragments inasfar as they were visible in the entire extent. Determination of the summary length of lechatelierite fibers in the moldavite mass was carried out by means of Konta's method (1969) by measuring under the microscope in toluene immersion. The length of lechatelierite fibers measured in moldavite mass under immersion in toluene and the attainable observations under the microscope were divided by the volume of the observed layer.

Results and Discussion

Figure 1 shows a group of lechatelierite fragments separated from the solid phase of moldavite rinsing waters. It appears that the fine-grained layers permeated by clay are richer in lechatelierite fragments than coarse layers easily permeated by water. This can be connected with dispersion of fragments into a higher volume by the permeating water. /142

Figure 1.

Obr. 1 Několik lechatelieritových úlomků, separovaných ze sedimentů v okolí vltavínu. Zvětšení 1 : 46
Several lechatelierite fragments separated from the sediments surrounding the moldavites. Scale 1 : 46



◀ Obr. 2 Závislost četnosti výskytu lechatelieritových úlomků, separovaných ze sedimentu, na jejich délce. Statistický soubor obsahoval 228 kusů
Occurrence rate dependence of lechatelierite fragments separated from the sediments according to their length. The statistical set consisted of 228 fragments

Figure 2 shows the relationship between the number of isolated lechatelierites and their length. The relatively high average length of lechatelierites from this set (228 pieces--average 0.55 mm) can be due to the methodology of isolation wherein a part of very small fragments escapes attention.

Figure 2.

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Obr. 3 Schématické znázornění vltavínu z Vrábče s vyznačením políček A — E, na kterém bylo provedeno sčítání lechatelieritových úlomků
Schematic diagram of moldavite No 354 with indication of fields A — E used for the summation of lechatelierite fragments

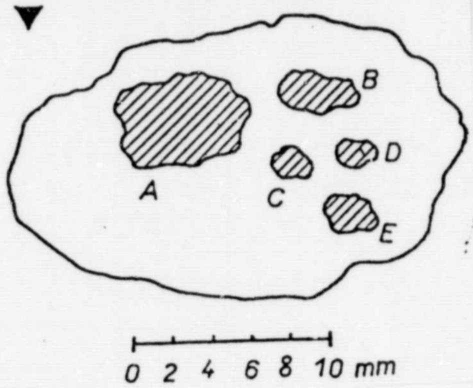

Figure 3 shows a graphical representation of moldavite no. 354 with delineation of fields (marked A-E) with its preserved original layer.

Figure 3.

Column 2 in Table 1 shows the number of lechatelierite fragments in individual fields. This table also shows the area of the fields (column 3) and the concentration of fragments in these fields in pieces per sq mm (column 4). From the determined average length of these fragments (0.36 mm) and their number is calculated the overall length of lechatelierite fragments in individual fields in a 1 sq mm area (column 5).

From these data and from the average length of lechatelierite /143 fragments per cubic mm (0.62 mm) it is possible to determine the mass that had to be etched off this moldavite to produce an accumulation of the corresponding amount of lechatelierite fragments. The thus computed value ranges between 2.6-4.5 mm (average 3.5 mm) for individual areas (column 6).

We regard this value as the lower limit, because it is more probable that a part of lechatelierite fragments failed to be included, rather than that there occurred a local accumulation of fragments in the surveyed spots. In addition, consideration must be given to the fact that in spite of their chemical resistance lechatelierites themselves are subjected to the effects of etching and mechanical factors. /144 Such damage to lechatelierite is borne out by Figure 4 showing a highly magnified fragment with localized corrosion. It is of interest to note the regularity with which this fragment had been etched.

Obr. 4 Silně korodovaný lechatelieritový úlomek s patrnou pravidelností leptání. Zvětšení 1 : 144
Considerably corroded lechatelierite fragment demonstrating apparent regularity of etching process. Scale 1 : 144

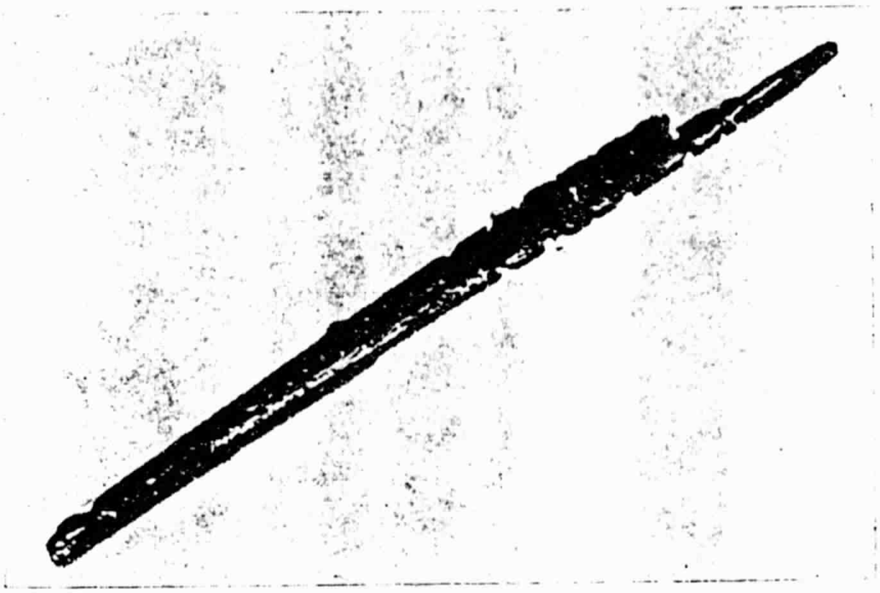

Figure 4.

As the length of lechatelierite protrusions on the surface of moldavites only very exceptionally exceeds 2 mm, the computed values indicate that a large part of lechatelierite fibers that had been bared by etching should be dispersed in the form of fragments throughout layers yielding moldavites, as has been confirmed by other finds of lechatelierite fragments in the vicinity of other moldavites.

The determined values of the etched off surface layer are somewhat lower than those cited in references (Rost 1967). The difference could be accounted for by the fact that in our case the thickness of the etched-off layer was determined after imbedding in the sediment.

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