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A QUANTITATIVE ANALYSIS OF THE NUMERICAL DENSITY AND THE DISTRIBUTIONAL PATTERN OF PRISMS AND AMELOBLASTS IN DENTAL ENAMEL AND TOOH GERMS

I. A LAPPING MACHINE FOR MINERALS AND MINERALIZED TISSUES WITH CONTINUOUS RECORDING OF LAPPING PROGRESS

by
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INTRODUCTION

Many techniques and machines for the preparation of thin ground sections of dental enamel have been introduced (*Bödecker*, 1926; *Gustafson*, 1948; *Hallen & Röckert*, 1960; *Hammarlund-Essler*, 1955; *Klein et al.*, 1951; *Laude et al.*, 1949; *Meyer*, 1925; *Sundström*, 1966; *Welander*, 1946). Other authors have carried out enamel investigations based on a serial surface grinding technique (*Fosse*, 1964; *Freiberg*, 1939; *Schnizer*, 1925; *Yosida*, 1938). The present author described a machine capable of preparing ground sections and of performing serial surface grindings with automatic checking of the grinding process in a preset position (*Fosse*, 1954). However, during the first stages of an extensive quantitative analysis of dental enamel which was carried out by this author, the need for a grinding machine combining the following qualities, became obvious:

1. Highest possible degree of accuracy.
2. Measurable grinding progress calibrated in microns.
3. Adjustable automatic checking point.
4. Smallest possible mechanical stress on the specimen during grinding.
5. Wide range of applicability.

Such a machine was constructed in collaboration with Chr. Michelsens Institute in Bergen which built the prototype to be described in this paper.

LAPPING MACHINE

Fig. 1 shows the lapping machine which is of sturdy construction, its weight being in the neighbourhood of 50 kgs. Its frame and working parts are made almost exclusively of cast iron of liberal dimensions in order to acquire rigidity.

The frame, shafts, bearings and electrical motors are concealed by a wooden casket, the dimensions of which are 52×42×23 cms.

The letter A in Fig. 1 designates the lapping disk which operates at a speed of 24 r./m. The material is cast iron and the disk has a diameter of 35 cms. and a mean thickness of 3 cms. It rests on a flange, with a diameter of 15 cms. The flange is part of a short, 4 cm. thick vertical shaft that rests in a thrust bearing. A handle may be fitted and secured in the center, to remove the disk from its supporting flange.

The letter B in Fig. 1 indicates an arm that swings about a vertical shaft denoted by the letter C. The arm may be raised or lowered along the shaft by the handle labelled D. The letter E designates two set screws which clamp

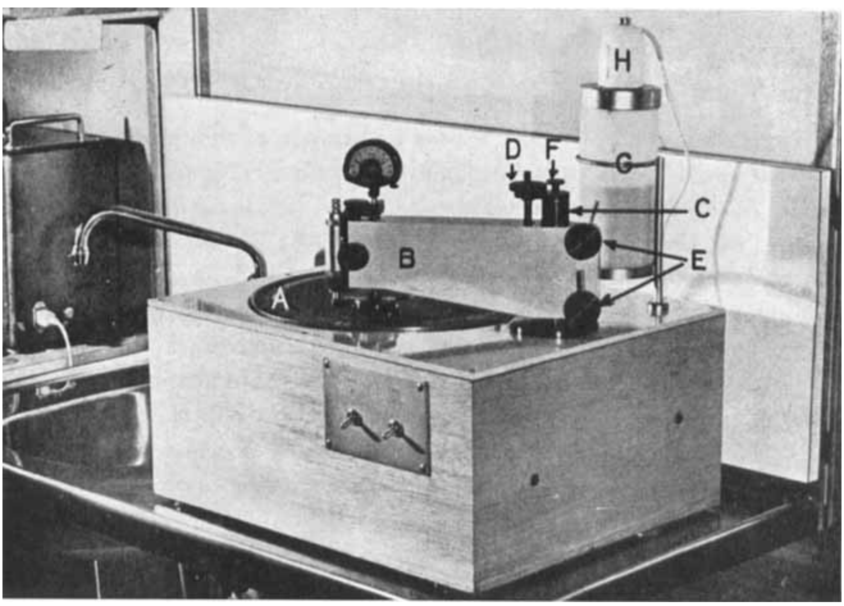

Fig. 1. The lapping machine. The letter A denotes the lapping disk. The letter B designates the object arm that may oscillate about the shaft marked C. A wheel to alter the height of the arm of the shaft, is indicated by D. Set screws to clamp the arm to the shaft are designated by E. The letter F denotes the clutch handle by which the arm may be released from the driving unit, so that its free end may be swung to the right. A vessel containing the lapping (compound) and its suspensory medium is indicated by G. The letter H designates the motor driving a little propeller that serves to keep the lapping compound in suspension.

the arm rigidly to its shaft. The letter F denotes the handle of a cluch that connects the arm to a driving unit. When this handle is lifted, the free end of the arm may be swung to the far right in order to remove the object carrier. The driving unit which is connected to the shaft marked C keeps the free end of the arm and the object carrier moving in a slow sweeping motion along the radius of the disk. The frequency is 18 times per minute.

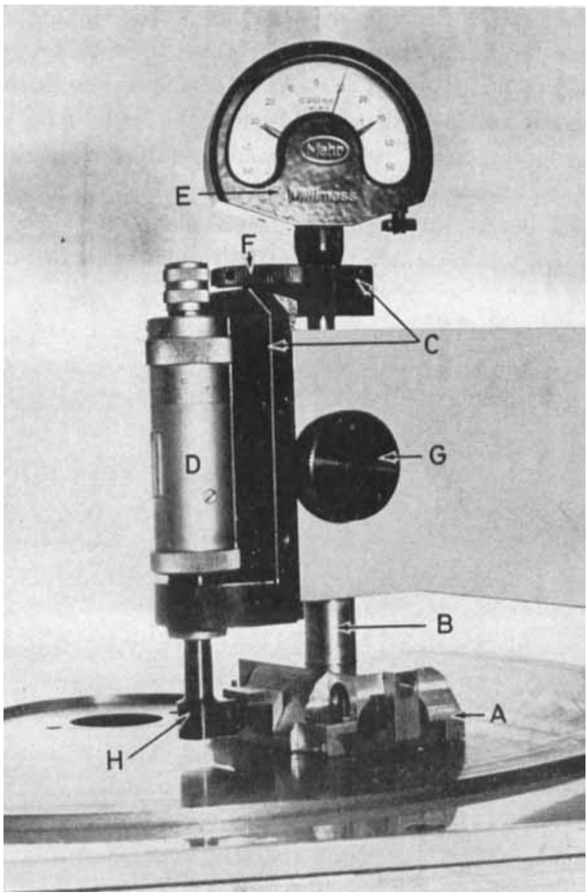

Fig. 2. The object carrier and measuring unit at the free end of the arm. The head of the object carrier is denoted by the letter A, the guide shaft of the object carrier by B, the measuring piece by C, the micrometer check-screw by D and the microcator by E. The letter F denotes the wheel by which the measuring piece may be raised or lowered. The measuring piece carries the micrometer check-screw and the microcator. A set screw to lock the position of the measuring piece is labelled by the letter G. The letter H denotes the catch of the micrometer check-screw that interlocks with the extension of the object carrier (labelled C in Fig. 3) and serves to stop its descent.

Separate motors operate the lapping disk and the object arm. If one single motor were to furnish both the arm and the disk with power, a synchronization pattern between the motion of the object and the revolutions of the disk would ensue and result in an uneven wearing of the disk.

The letter G in Fig. 1 denotes a reservoir and a mixer of lapping compound and its suspensory medium, kerosene or a mineral oil of low viscosity. The small motor on top, designated by H, is connected to a vertical shaft inside the cylindrical plastic vessel. To this shaft is fitted a little propeller to keep the contents in agitation when required. The lapping compound is kept in suspension by the propeller and reaches the disk by a tube with a spring clip attached. The excess suspension on the disk is drained off via a conduit along the disk periphery to a tube at the back of the machine.

Fig. 2 offers a close-up of the object carrier and the measuring unit. The letter A designates the head of the object carrier which is pressed down onto the lapping disk by its own weight. Its vertical motion is guided by the shaft marked B, which moves in a vertical cylindrical bore in the arm.

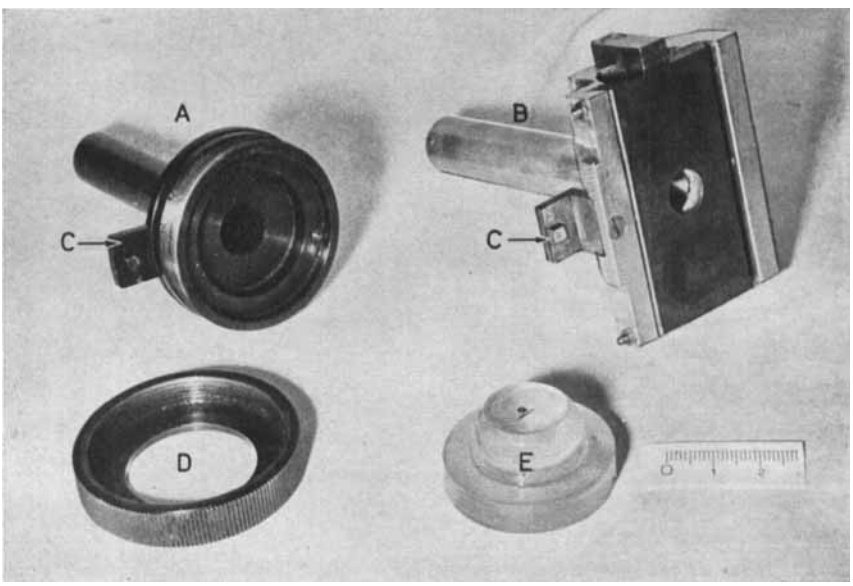

Fig. 3. Object carriers. The object carrier made of steel is designated by the letter A. The letter B denotes an aluminium object carrier designed to carry tooth slabs which are to be lapped down to thin transparent sections. The letter C indicates extensions that interlock with the check-screw catch to arrest descent of carrier. Front ring of carrier A is indicated by D, and a plastic column with flange to be placed in the circular depression of the steel object carrier is marked by the letter E.

The measuring-piece marked C carries the micrometer check-screw designated by D and the microcator marked E. By means of the little wheel marked F, the measuring unit comprising C, D and E may be raised or lowered along a dovetail rail that fits into a vertical groove in the arm. The letter G designates a set screw to lock the position of the measuring unit.

As the name implies, the purpose of the micrometer check-screw is to check the descent of the object carrier in a pre-set position. The microcator serves to indicate the progress of the object carrier, or, if the »zero-point» is known, to tell how much has still to be lapped. Each interval on the scale represents 1 μ. (This microcator is interchangeable with one that has a greater measuring range and where each interval represents 10 μ).

Fig. 3 shows two object carriers. The one indicated by A is made of steel and is intended to carry the plastic columns which are to be ground down in series of planoparallel surfaces. It weighs 220 gm. The other carrier, designated by B is made of aluminium and weighs 173 gm. It carries a removable lapped steel plate in front, and upon which tooth slabs are glued directly to be lapped into thin transparent sections.

To explain the operational mode of the machine, it is necessary to describe the lapping of thin transparent sections and the performance of serial surface lappings separately.

LAPPING OF TISSUE SECTIONS

Dental enamel is undoubtedly the most difficult tissue to grind down into very thin sections. For this reason the grinding or lapping of tooth sections will be dealt with here.

In a Gillings Sectioning Machine* the whole tooth is cut up into fairly thick slabs (150—200 μ). The sawn sections of the tooth, from which the frame of embedding material should be removed, are individually ground and polished thoroughly on one surface.

It is necessary to determine the zero-point of the steel plate before the sawn slab is mounted on it. This is done by placing the steel plate in its mount on the carrier onto the lapping disk. The measuring point of the microcator rests on the plane end of the guide shaft of the carrier. If the position of the carrier does not come within the measuring range of the instrument, the position of the entire unit is adjusted by the wheel denoted by F in Fig. 2, until the instrument needle swings into the range of the scale. The position of the needle on the scale when the set screw marked G in Fig. 2 is tightened is the zero-point.

* Manufactured by Hamco Machines, Inc., Rochester, N.Y., U.S.A.

Before the tooth slabs are attached to the steel plate, the micrometer check-screw marked D in Fig. 2 is turned until the catch, designated by H in Fig. 2, touches the extension of the carrier, designated by C in Fig. 3. The micrometer check-screw must be turned no more than is necessary to cause a slight movement of the needle. This is to ensure that the zero-point of the micrometer corresponds to the zero-point of the microcator.

Having thus determined the zero-point on both instruments, a check-point may be chosen by turning the micrometer check-screw further, so that the catch marked H in Fig. 2 is raised above the zero-point. The difference between the number read off at the check-point and the number corresponding to the original zero-point (touching-point), will be the thickness of the mounted section when lapping is completed.

Having determined the zero-point and the check-point the steel plate which rests on three tempered steel taps in the carrier is removed by loosening a set screw in the carrier.

The tooth slabs are fastened by the polished surface on the steel plate by means of Eastman 910 adhesive or one of the cheaper conventional fast hardening glues. The slabs should be pressed firmly onto the plate to obtain an even and the thinnest possible film of glue between specimen and steel-surface.

Starting with a thickness of 200 μ, one slab may be lapped down to a thickness of 20 μ within 20 minutes.

At the conclusion of the lapping one may observe directly on the microcator the progress of the process and the remaining thickness of the section. If a check-point has been set on the micrometer, the needle of the microcator will settle on a zipher corresponding to the pre-set thickness.

The section can be controlled at any point in the process by releasing the clutch of the object arm and swinging it aside to free the carrier. And if desired the section can be checked in the microscope by incident light since the steel plate may be removed from the carrier and be replaced without altering the originally determined zero-point by more than a few microns at most.

Axial movement at the periphery of the lapping disk is $\pm 2\ \mu$ and is indicated by corresponding oscillations of the microcator needle, since the carrier floats freely on the disk. If the zero-point has been read off at the maximum plus value of this axial movement, the maximum oscillating position of the needle always indicates the remaining thickness of the section. Thus the size of the axial movement does not interfere with the accuracy of the lapping.

Having finished the lapping, the ground sections are removed from the steel plate by aceton if an ordinary glue has been used, and by dimethylformamide if Eastman 910 has been applied. The sections are then treated through alcohol and toluol to be mounted in Eukitt on a microscopic slide. In routine preparation of tooth sections a thickness of 30 μ with intact enamel was easily acquired. Below 15 μ segments of the enamel might be lost. In such cases the remaining fragments had no cracks and were in perfect condition for microscopy.

SERIAL SURFACE GRINDING

A plastic column with an embedded tooth is shown in Fig. 4. The letter A indicates the lapped surface in the center of which the etched and stained tissue may be examined in incident light. If substage illumination is used, the light beam from below is reflected towards the center of the lapped plane by the parabolic rim marked B (*Fosse*, 1964). This rim may be reshaped in a lathe if repeated lappings reduce the height of the column to a great extent.

The basal flange denoted by C serves as a hold for the front ring of the object carrier.

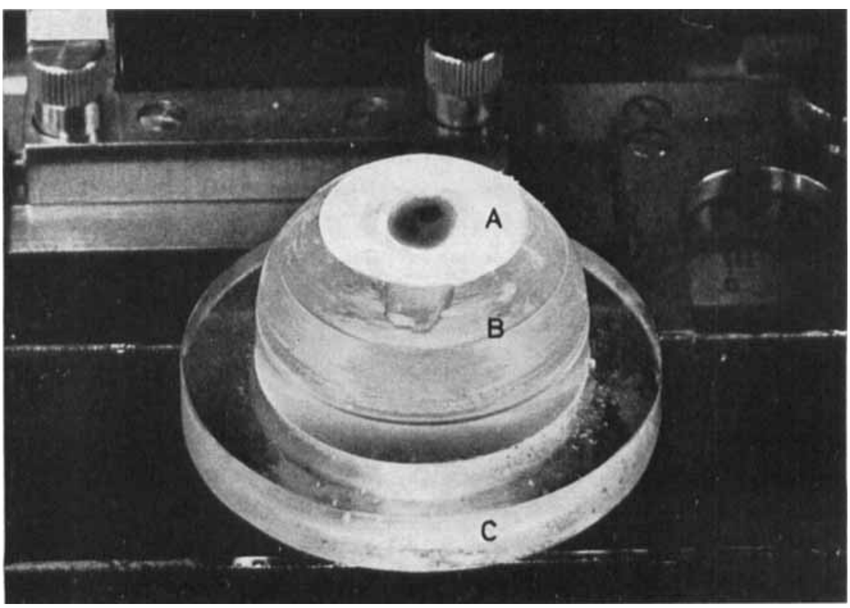

Fig. 4. A plastic column containing a tooth. The lapped surface is indicated by the letter A. The letter B denotes the parabolic rim acting as a mirror to the vertical light beam from below. The flange by which the column may be fastened to the object carrier of the lapping machine is designated by the letter C.

In Fig. 3 the front ring, marked D, is screwed off the carrier designated by A, to demonstrate how the basal flange of the plastic column may be placed on the cylindrical step in the circular depression of the carrier. The ring when screwed into position provides a rigid hold on the flange.

The depression of the carrier has been provided with a tiny pin in the periphery. This pin fits into a groove in the plastic flange. In Fig. 3 it may also be seen that the extensions on the carriers have been provided with small pins. These fit into a corresponding slit in the micrometer catch. The pins will prevent rotation of the plastic column and the object carrier and also ensure that the specimen will always be replaced in the same position when it has been removed for examination.

The sweeping motions of the arm during the lapping process should also prevent the occurrence of streaks in the lapped surface. However, the lapping compound is of such a fine grit that even when the specimen is allowed to remain in a fixed position in relation to the disk, no streaks can be seen. In fact, by stopping the sweeping arm in different positions, one may speed up or slow down the lapping process. Sweeping is mainly necessary to obtain an even wearing of the disk.

The author used lapping compounds,* where the mean size of the grinding particles varied from 7 to 4 microns in the different compounds.

Lapping a series of planoparallel surfaces with a pre-set distance between them is carried out by using the micrometer check-screw. Prior to each successive surface lapping the micrometer check-screw is turned to the new position corresponding to the desired interproximate distance.

If the interproximate distance is lower than 30 μ, the series should be read directly from the microcator.

Series with interproximate distances ranging from 10 μ upwards, have been prepared by the present author.

TESTING OF ACCURACY

Measurement of distance between lapped planoparallel surfaces

A test series was carried out to estimate the actual values of the interproximate distances between the lapped surfaces. In this series the predetermined constant interproximate distance was set to 10 μ.

The specimen was a 500 μ thick tooth section which was glued to the steel plate. After each lapping, the steel plate was removed and placed on the stage of a microcator.** The remaining thickness of the section was measured

* United States Products Co. 518, Melwood Avenue, Pittsburgh, Pa., U.S.A.
** Manufacturer C. E. Johanson, Eskilstuna, Sweden.

on a fixed point. To estimate the error in measurement, this thickness determination was carried out twice for each lapped surface.

In Table I the depth differences between the lapped surfaces in this series are listed. The second column gives the first measurements and the third column the second or control measurements. The values in the fourth column are the differences between the results of the first and the second measurements for each lapping.

The mean of the first measurements was 9.66 μ with a standard deviation of 2.76 μ. By the control measurements the corresponding values were 9.52 μ and 2.83 μ respectively.

Table I

The interproximate distances between 13 lapped planoparallel surfaces

Lapped surfaces	Distance between consecutive surfaces		$x_i - y_i$
	1. meas. x_i	2. meas. y_i	
1— 2	5,00	5,25	0,25
2— 3	14,50	13,50	1,00
3— 4	7,75	10,25	2,50
4— 5	11,50	11,00	0,50
5— 6	8,00	5,75	2,25
6— 7	11,00	12,00	1,00
7— 8	7,25	7,00	0,25
8— 9	7,10	6,50	0,60
9—10	8,65	9,00	0,35
10—11	11,25	10,50	0,75
11—12	11,50	10,25	1,25
12—13	12,50	13,25	0,75
Mean	9,66	9,52	(0,95)
Stand. dev.	2,76	2,83	(0,70)
$\sqrt{\frac{\Sigma (x_i - y_i)^2}{2n}}$ =			0,837

The values are given i microns. The lapping distance indicated by the machine was 10 microns for each surface.

Measurements of planoparallelism

The thickness of ten sections was measured at two points on the upper surface of each section. The distance between the points was 11 mm. and the reference plane was the top surface of the slide. The mean difference of thickness between the points was 1.95 μ with a standard deviation of 1.16 μ. The maximum difference of thickness was 3.5 μ. The error of the measuring method in this case constituted 0.837 $\mu \cdot \sqrt{2}$.

SUMMARY

The author described a machine for the preparation of very thin planoparallel sections or the performance of serial planoparallel surface lappings of brittle tissues, particularly dental enamel.

The grinding process can be automatically checked at a predetermined lapping distance. The thickness of the tissue still to be lapped is also constantly indicated by a microcator when the machine is in operation. Essential to the capacity of the machine is the low revolution velocity of the lapping disk, viz. 24 rev./min., and the low constant pressure on the specimen to be lapped.

Control measurements of the interproximate distance between the surfaces of a series where the predetermined constant distance was set to 10 μ, showed a standard deviation of 2.83 μ for the actual distances of the series. The mean distance in this test series was 9,52 μ.

In a series where the microcator was reset to zero-position after each lapping, the standard deviation was reduced to 1.14 μ.

The mean difference of thickness between two points with a distance of 11 mm. between them was found to be 1,91 μ, which indicated the deviation from parallelism for ground sections.

The author feels that the machine will meet a great many demands in the general field of high precision grinding and lapping technique.

RÉSUMÉ

MACHINE POUR USURE DES MINÉRAUX ET DES TISSUS MINÉRALISÉS, AVEC ENREGISTREMENT CONTINU DE L'USURE EN COURS

L'auteur décrit une machine pour la préparation de coupes planoparallèles très minces ou pour la confection de séries d'usure de surfaces planoparallèles de tissus fragiles, et particulièrement d'émail dentaire.

Le processus de meulage peut être automatiquement contrôlé à une distance d'usure préalablement déterminée. L'épaisseur de tissu restant à user

est de même constamment indiquée par un indicateur micrométrique pendant le travail de la machine. Un facteur essentiel pour le fonctionnement de la machine est la faible vitesse de rotation du disque, soit 24 t/min, ainsi que la pression faible et constante, appliquée sur la pièce à user.

Dans une série au cours de laquelle la distance constante préalablement déterminée avait été réglée à 10 μ, des mesures faites pour contrôler la distance interproximale entre les surfaces ont montré qu'il existait un écart-type de 2,83 μ pour les distances réelles dans la série. La distance moyenne dans cette série expérimentale était de 9,52 μ.

Dans une série ou l'indicateur micrométrique était remis au zéro après chaque usure, l'écart-type était réduit à 1,14 μ.

La différence moyenne d'épaisseur entre deux points distants de 11 mm était de 1,91 μ, ce qui exprimait le degré de manque de parallèlisme des coupes par usure.

ZUSAMMENFASSUNG

EINE SCHLEIFMASCHINE FÜR MINERALE UND MINERALIZIERTE GEWEBE MIT FORTLAUFENDER ANWEISUNG DER RÜCKSTÄNDIGEN DICKE DES GEWEBES

Der Verfasser beschrieb eine Schleifmaschine für die Verfertigung der planparallellen Dünnschliffe, oder von Serien der planparallellen Anschliffe, besonders von Zahngeweben.

Die Schleifung oder »lapping» möchte bei einer bestimmten Schleifstrecke automatisch unterbrochen werden. Die Dicke des Gewebes, das noch weggeschliffen werden soll, ist stets durch eine Messuhr während der Schleifung gezeigt.

Für die Leistungsfähigkeit der Maschine ist die langsame Umdrehungsgeschwindigkeit der Schleifscheibe sehr wichtig. Sie rotiert mit einer Geschwindigkeit von 24 Umdrehungen per Min. Ein Vorteil ist auch der geringe und konstante Druck auf dem Präparat während der Schleifung.

Kontrolmessungen von dem Abstand zwischen den einzelnen Schleifplänen in einer Serie wurden gemacht. Der im voraus eingestellte konstante Abstand war 10 μ. Der mittlere Abstand in dieser Prüfungsserie war 9.52 μ, mit S.D. gleich 2,83 μ.

In einer anderen Serie wo die Messuhr nach jeder Schleifung Nullgestellt wurde, wurde S.D. auf 1.14 μ reduziert.

Der mittlere Unterschied der Dicke zwischen zwei Pünkten mit einem gegenseitigen Abstand von 11 mm. war 1,91 μ. Dieser Versuch zeigte die Abweichung von Parallellität der Dünnschliffe.

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