Giovanni Battista Amici's Immersion Microscope Large Model, at the Museum for the History of the University of Pavia

GUSTAVO MERICO (*)

SUMMARY - *In April 1999 Amici's immersion microscope held in the Museum for the History of the University of Pavia was analyzed by an expert microscopist, and the result of the analysis is published here.*

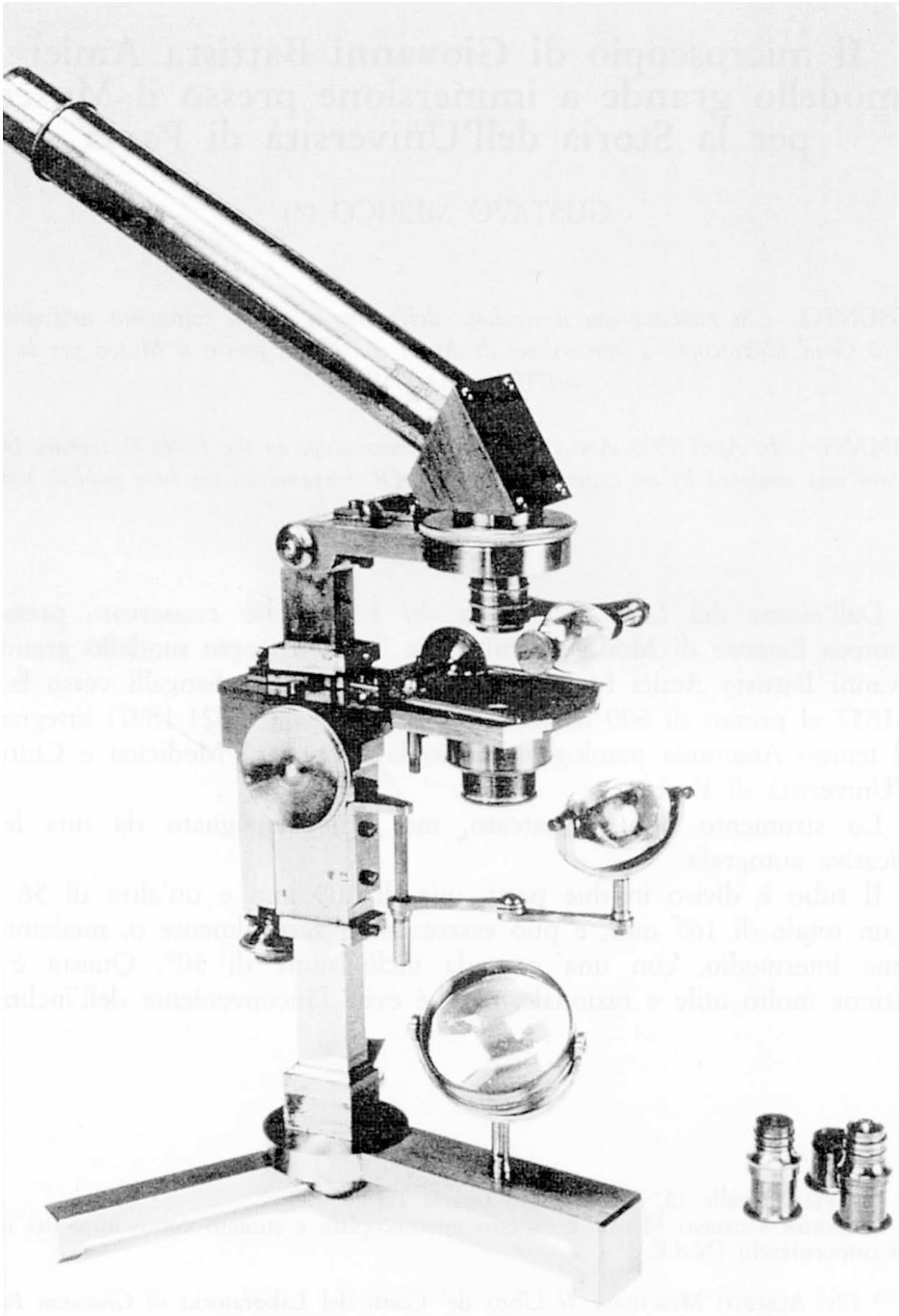
The *Workshop Account Book* held in the Estense Library in Modena reveals that a large model of Giovanni Battista Amici's microscope was furnished to Prof. Giacomo Sangalli towards the end of 1857 at the price of 600 francs[1]. Prof. Sangalli (1821-1897) at that time taught Pathological Anatomy in the Faculty of Medicine and Surgery at the University of Pavia.

The instrument is not marked but is accompanied by a handwritten explanatory letter.

The tube of the microscope is divided into two parts, one of 109mm and the other of 56mm, for a total of 165mm and can be used vertically or, through an intermediate prism, at a comfortable 30° inclination. This is a very useful and rational solution because it avoids the disadvantage of inclining the slides with the possible slipping off of the coverglass and loss of the liquids. It's an advantage, however, which implies the loss of a small percentage of light (from 10 to 15%). Amici suggests using the two pieces of the tube without the prism (optical length of 200mm) for measuring, while he advises using the prism and one part of the tube for observations (250mm).

* via Molzelle 15, 25047 Darfo Boario Terme (BS). Dr. Gustavo Merico is an expert microscopist and esteemed authority on 19th century microscopes (ed. note).

[1] Cf. ALBERTO MESCHIARI, *Il* Libro de' Conti del Laboratorio *di Giovanni Battista Amici,* "Atti della Fondazione Giorgio Ronchi", 1 – 2001, p. 105.



The instrument has a flat folding tripod base, each foot of this base is 9.0cm long. These feet sustain a rectangular-section pillar 15cm long, at the top of which a horizontal bar is hinged with a compass joint. This horizontal bar ends in a wheel on which both the optical tube and the objective lenses are fitted. The bar can be moved up by 90° for an easy substitution of the objective lenses and their immersion in liquids.

The translation stage can only be moved in a longitudinal sense using a knob placed on its left, and it is attached to a large sleeve which surrounds the pillar to which the bell-shaped, knurled knob for micrometric focusing is attached. To the right another large knob with pinion and toothed rod provides the ordinary focusing. Below the stage a cylinder containing a hemispheric flint glass lens with a high refraction index is screwed on; it acts as a condenser of light. It is hemispheric (11mm diameter x 5.5mm radius) with a focal distance from the plane surface of 4mm, and it has the numeric aperture of 0.50 (not aplanatic). This system is used for illuminating transparent objects only, with centric or slightly oblique light. The light is conveyed by the moveable mirror attached to the front bar of the base. This mirror has two plane faces on one of which a plano-convex lens is applied to converge the light onto the specimen.

The instrument has two right-angled prisms in flint glass, with two convex and one plane face (which Amici called plano-convex prisms). The upper one is attached to the horizontal bar with a moveable rod, and it is used to illuminate the specimens obliquely from above. The other is attached to the sleeve under the stage and can be moved and fixed in any position for an oblique illumination from below. These prisms, if used carefully, offer very useful illumination for the resolution of the tests and for studying the delicate structures of the specimens.

The objective lenses[2] are composed by simple or achromatic elements contained in marked brass rings which can be screwed onto each other; the lenses are held in place with Chio's mastic and with crimped edges.

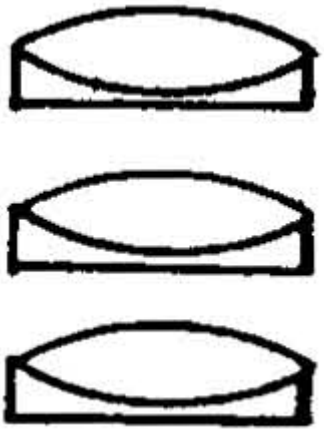
The dimensions are 3cm x 1.5cm on the average and their screw pitch is the 48G, or 3/32 of a British inch, with a diameter of 14.9mm. A small cover is screwed on before putting them away in holes made for them in the carrying case, without using a full sheath (I found the same system in "The Popular Microscope" binocular model produced by Smith Beck & Beck, London, No. 4135 of 1864).

Inside the objectives have been blackened with lampblack paint only on the upper part where there is the screw pitch incision and, different from English objectives, but analogous to those constructed by E. Hartnack, who imitated Amici, there is no internal diaphragm.

[2] Generally Amici called the objective lenses *series of objectives,* while *objectives* were the lenses by which they were composed.

SERIES I, to be used dry: focal distance 26.9; individual magnification 9.27x, 1" (with long tube): Numerical Aperture 0.32. The planarity is acceptable, good clarity.

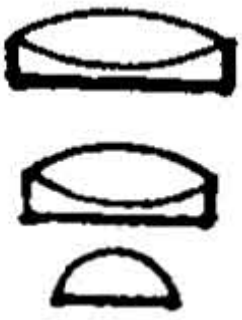
Dimensions of the three elements: ⫩ 6mm, Ø 8 mm.
Indicative scheme:



SERIES II, missing. To be used dry, individual magnification 20x, ½", it had a small Lieberkühn mirror for illumination from above.

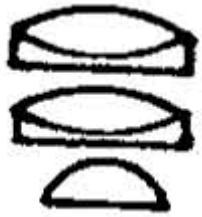
SERIES III, to be used dry: focal distance 17.5mm, magnification 58.7x, 1/6", Numerical Aperture 0.65, for uncovered specimens or with very thin coverglass. Work distance 0.6mm.
Good planarity, image slightly dim due to defect in the adhesive of the upper element.

Diameters of the elements: Ø 4.8 mm, Ø 4 mm, Ø 2.5 mm
Indicative scheme:

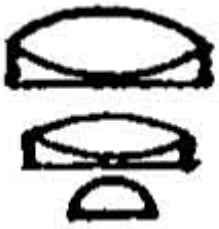


SERIES IV, to be used dry, same magnification and focal distance, 1/6", Numerical Aperture 0.60; to be used with a glass 1.2 mm thick, for compressors. Work distance of 1.1mm (with glass a distance of 0.35 mm often remains). The first and second elements have slightly turbid adhesive and the image is therefore dimmed.

Diameters of the elements: Ø 4 mm, Ø 4 mm, Ø 2.7 mm
Indicative scheme:



SERIES V, to be used in water immersion, magnification 64x, 1/6", focal distance 3.9 mm. Numerical Aperture of 0.77 and work distance of 1.1mm. This objective is also appropriate for use with glass 1.2 mm thick of a compressor, but it is much less sensitive to the variations of the thickness of the coverglass, which can vary from 0.45 to 1.5 mm! (the maximum resolution is at 1.2 mm). There is a crystallization in the adhesive in the first and second element. Image contrast is average, with overall optical return better than that of the previous objective.
Diameters of the elements: Ø 4.7 mm, Ø 4.5 mm, Ø 2.2 mm
Indicative scheme:

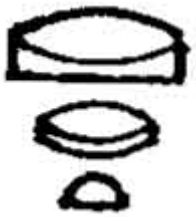


Compared to a dry objective No. 7 constructed by E. Hartnack in 1861, it has a definition very close to and brightness analogous to that of Hartnack's, even if this latter has a Numerical Aperture of 0.84.

SERIES VI, to be used in water immersion, magnification 112x, 1/11" focal distance 2.23 mm, work distance 0.25 mm. Numerical Aperture 0.91, not particularly wide among those adopted by Amici. At the edge of the upper element there is a slight dimming of the adhesive, with a negligible effect.

Examined with the Abbe test, this objective is exempt of significant spherical aberrations with coverglass from 0.10 to 0.24 mm of thickness (all of the coverglasses of the test). Thus, as the maker wished, there was no need for the delicate and costly Lister-Ross system of correction, meaning great ease of use and economic savings. I also have to emphasize how advantageous the immersion in water is, for the greater quantity of light of the very oblique rays, coming from an object, that the objective manages to transmit.

Diameters of the elements: Ø 4.5 mm, Ø 3.1 mm, Ø 1.3 mm
Indicative scheme:



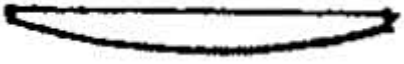
In all of the objectives the spherical aberration is well corrected and the chromatism is compensated in a surprising way through the use of different types of glass (from three to five) with a different dispersion of the spectrum. A residual spectrum, outside the focal area, can be noted; it is reduced to light, brown and bottle green tones, like in modern semiapochromatic objectives, even if there is not the same sphero-chromatic correction.

All of the objectives, with the exception of the first, give a slight greenish dominant in colour photographs, since a green borosilicate flint, not totally compensated by a red borosilicate flint, was used.

The eyepieces, which are a bit difficult to screw into place, have a scheme of the Huyghens type, but the eye lens is achromatic (doublet). In this way Amici best corrected the residual chromatism of the magnification, or lateral, at the periphery of the field, which was due to the difference of the optical scheme of the various objectives employed. This effect is needed for the 15x eyepiece, while in the 10x one the regulation is needed only to bring into focus a little measuring grid engraved onto the plane face of the lower lens, of which one has an achromatic image.

This type of eyepiece, which was presented by the maker at the Meeting in Pisa in 1839, was received by Prof. Pieter Harting of Utrecht in 1847 as well.

Indicative scheme:



In the oak carrying case where the instrument is put away, there are some accessories wrapped up in handwritten notes.

Among the slides which are to be used to verify the perfection of the objectives (test objects), there is one which is truly important for the history of the microscopy. It is a specimen which Amici obtained by mounting a small quantity of fossil soil [Farina

fossile], donated to him by Prof. Christian Ehrenberg and coming from Lake Lillhagsion in southern Sweden, in balsam from Canada.

Here can be seen the thecae[3] of a beautiful diatom at that time called the *Navicula Amici* by microscopists. It is in reality the *Navicula serians KTZ*, and more precisely the variety *minor Grun*[4]. The number of the cross striae of the thecae is of 29 on the average in 10μm, and to see them distinctly an objective with a Numerical Aperture of 0.80 should be used. But to admire the design in all its particulars (pentagram engraving) a greater aperture is needed. An objective constructed with the simple hemispherical front lens of Amici is therefore needed[5].

[3] The thecae are the silicified (in chalcedony) parts of the membrane of the one-celled algae called Diatom which unite by fitting into each other and form a "box" called a frustule. Diatoms are called so only when integral.

[4] An acceptable classification of the *Navicula Amici*, even if some authors have recently proposed new general terms, is the following:

Class	BACILLARIOPHIYCEAE (o DIATOMEAE)
Order	Pennales
Family	Naviculaceae
Group	Anomoeoneis (Pfitzer) <some authors put this as the genus in the place of the following>
Genus	Navicula (Bory)
Species	serians (Kutzing), (= punctulata et lineata Ehrembergi)
Variety	minor (Grunow), (= brachysira Brebisson).

[5] The frontal lens of Amici is simple because formed by a single glass and it cannot be substituted by a compound achromatic lens. I have carefully examined different objectives constructed by Andrew Ross, Smith & Beck and Powel & Lealand from 1843 to 1852, with compound front lenses with spherical upper surfaces. These lenses give a surprising result, even if they do not satisfy the sine condition, at least up to a N. A. of 0.75. One cannot go beyond a N. A. of 0.80, however.