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The TWX-1 Folded-Optics Microscope

Monarch of the Folded-Optics Kingdom

Folded-Optics Microscopes: Part I
with an introduction to early field microscopes

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Introduction

This is the first Part of a series on folded-optics microscopes. Additional Parts will follow during the coming year. These papers will cover other folded-optics instruments including the seminal McArthur microscopes, Nikon H models, and the relatively inexpensive folded-optics microscopes designed by Rick Dickinson: the Lensman, Enhelion Micron, Meade Readiview, and Trekker. If both models of the Millenium Health Microscope (MHM) are available for general release within the next twelve months, the authors hope to provide an evaluation of what would then be the latest implementation of folded-optics instruments. In a previous paper we reviewed the Swift FM-31 and FM-31 “clone”.[i]

This first Part, appropriately in the authors' opinions, discusses the best folded-optics instrument made to date, the Chinese Army Portable Field Hospital Microscope, the TWX-1. A detailed description of this microscope in its social, political, and economic milieu is presented below, along with a description of its technical capabilities and the reasons for our conclusions about its supremacy among folded-optics instruments.

In the "Background" that follows, we use the term "field" in a quite broad sense to apply to microscopes not specifically designed for benchtop use. Thus, e.g., although little is known about how Leeuwenhoek used his microscopes, they were easily portable for field use, if desired. At the heavier end of the weight continuum is the Nairne chest microscope. Although not lightweight, it weighs less than early portable computers and, its rapid set-up and return from/to its stored position would have made it a reasonable choice for field work where appropriate transportation was available.

Background

Since this is our first paper in this series, we start with a slightly extended discussion of earlier microscopes that are at the beginning of the continuum of portable field microscopes that today include folded-optics instruments

Field microscopes have a long and fascinating history, which could fill an entire book, possibly many books. Thus, the following is provided to set the general background and historical ancestors of folded optics portable microscopes; it is not meant to be comprehensive. It covers only a portion of the more important instruments that were the background for later development.

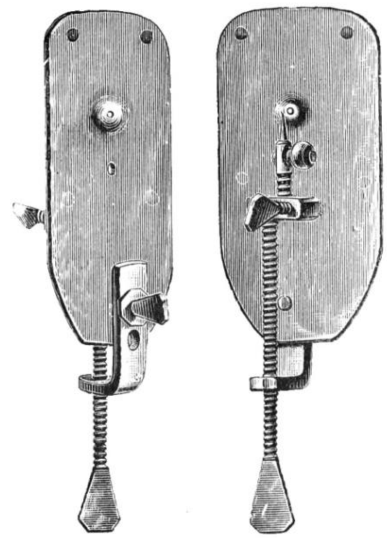

Figure 1. Leeuwenhoek's microscope (1673)

Simple Field Microscopes

Some of the earliest examples of portable instruments were the microscopes developed by Antony Philips van Leeuwenhoek. These were simple (single lens) microscopes (Fig. 1).[ii] The work of van Leeuwenhoek is discussed in a number of books, one of the more interesting is "Antony van Leeuwenhoek and his 'Little Animals' [iii],

> ... Mr. Leeuwenhoek showed us the circulation of the blood very well with his machine, though it was somewhat troublesome to manipulate, and would be even worse of making observations lasting over a long time, because you have to put the side of the *microscopium* where the lens is, against your forehead, and look upwards through the tiny glass; which after some time would become tiresome ... Yet one cannot sufficiently marvel at Mr. Leeuwenhoek's great diligence and industry, both in the making of observations and in the grinding of lenses, as also in the manufacture of the mechanical parts for his *microscopia;* albeit the latter are simple, and badly worked ... [iv]

As Brian Ford notes [v] Leeuwenhoek's microscopes used simple screws to move the objects to be viewed. However, these simple microscopes had magnifications, of about 250X at their greatest powers and can still accomplish today the work required for most scientific applications, although clearly with some difficulty in use.

Most of the early portable microscopes were simple microscopes, not only because with one lens they were easy to carry, but optically they provided better images than early compound microscopes. These early portable instruments include the 17th century fleaglass, a small magnifying glass often housed under a thimble like domed cover to look at, not surprisingly, small insects and fleas which were commonly available and provided some rather amazing and fascinating subjects for early microscopists.

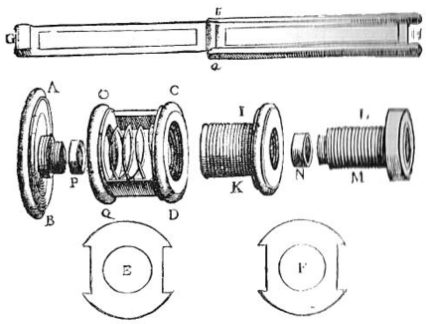

Figure 2. Hartsoeker's simple microscope

Other early simple microscopes include the Wilson screw-barrel, actually invented by Dutch microscopist Nicolaas Hartsoeker, (Fig. 2)[vi] possibly toward the end of the 17th century, and popularized by the UK's James Wilson. The body tube of this microscope has exterior threads that allow the microscope to be focused by threading the microscope tube inward or outward in its exterior holder.

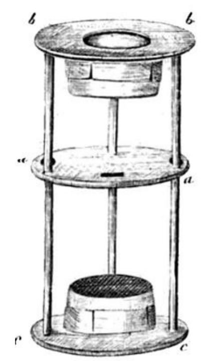

Figure 3. Withering botanical microscope

The Withering Botanical microscope (Fig. 3) [vii] of the late 18th century, is a small cylindrical microscope usually with two or three parallel circular plates with penetrations. Originally the top plate was circular. However, later versions have a more bar-like shape in place of the top circular plate. The top circular plate, or bar, often contained a simple dividing lens, the middle plate is for placing the specimen, and can be moved up and down for focusing. It often allowed for the insertion of a live box. The bottom plate provides stability. The bottom two plates usually have small "holes" or "grooves" just inside their circumference to allow for holding tweezers or stage forceps, a dissecting needle, and possibly other dissecting instruments. Two supporting rods run from base to top plate. The Withering microscope is usually made completely of lacquered brass and is less than 9 cm (3.5 inches) tall and typically housed in a two-section circular maroon colored pasteboard or wooden case.

Figure 4. English botanical microscope

Toward the end of the 18th century the English botanical microscope (Fig. 4) became popular. These were often supplied with a variety of lenses that could be used by themselves or in combination, and usually included a live box or other means of holding pond water for examination. They often, but not always, were mounted on top of their storage boxes. They were frequently focused by sliding the stage carrying the object up or down. There was, in later instruments, often a fine focusing knob atop the rear circular pillar. These instruments allowed open access to objects and thus allowed dissecting where the central penetration was not too large, or a clear or opaque plate could be inserted.

Various versions of the compass microscope introduced in the 18th century, and its descendants which often lacked the Lieberkühn (reflector around the lens) were readily available for at least the next century. [Note: The Lieberkühn was not invented by Lieberkühn, but was used for many years before his name became associated with it].

Figure 5. Folding versions descended from the original compass microscopes

Figure 6. The "flower microscope", a fixed version descended from the original compass microscopes

Descendants of the compass microscope were quite popular because of their size and relatively low cost. They were typically unsigned and available in both folding models with turned ivory or wood handles and were typically housed in an étui (Fig. 5) and fixed, non-folding, versions (Fig. 6) which was even less expensive to produce.

These microscopes are, for the folded versions, approximately 10 cm (3.94 inches) long unfolded and 7 cm (2.75 inches) long folded, and for the non-folding models approximately 12 cm (4.72 inches) tall. The non-folding models have a sliding specimen holder that moves inside a hole in the microscope's body to bring objects to focus in the field of view. As described in the *Edinburgh Encyclopaedia* of 1830, "*This microscope is one of the most simple, and the most convenient and is peculiarly fitted for being put into the hands of young persons, who are not capable of managing a more complicated apparatus*." [viii]

Later examples of the descendants of the simple microscope include the small inexpensive cylinder microscopes (Fig. 7) [ix]

Figure 7. Small simple cylindrical microscopes

Compound Field Microscopes

While simple microscopes were usually relatively inexpensive, they were fairly inflexible and difficult to use for extended periods. As a result, as early as the 18th century compound portable microscopes made their appearance.

Figure 8. Nairne chest microscope, c 1765

One of the earliest is the Nairne Chest Microscope (Fig. 8), which was really more a transportable than a portable microscope, as it would have been difficult to carry in one's pocket or a single hand. Nairne claimed to have invented this style of microscope that was hinged at its base to allow easy setup from its storage position, and easy return to that position. It was quite flexible and usually came with a Lieberkühn, fishplate and about 1/2 dozen objectives. Its primary problem, for the field microscopist was its size and weight, over 5 lbs 3 oz and almost 11 inches long, making it similar to early "portable" laptop computers, but making it unsuitable for use where only on-foot, as opposed to carriage or horseback travel was possible.

This microscope as well as others of similar size proved difficult to transport into the field and so other, smaller, field microscopes were developed during the 19th century. Including the Cary-Gould type microscope (Fig. 9), the Martin Drum microscope (Fig. 10 is a later and smaller descendant), and folding tripod microscopes, discussed in one of our earlier papers [x] .

Figure 9. Cary-Gould microscope, c first quarter 19th century

The Cary-Gould microscope was developed by Charles Gould one of William Cary's employees. The microscope was introduced at the end of the first decade of the 19th century. Its design is reminiscent of the English botanical microscope, with the major change being a compound, rather than a simple, microscope attached to the case. This microscope came in a great variety of configurations including ones attached to the top or side of the case. It is often signed by Cary, with the Cary name continued after his death by his nephews.

In 1877, the former editor of *The American Journal of Microscopy* had this to say about the then widely available smaller drum microscopes (Fig 10) [xi]:

> This form, although modern when compared with the microscopes of Adams, Baker, etc. is one of the oldest forms in use. ... and it is now too well known to need elaborate description, and as ***no microscopes of any value are ever constructed upon this plan***, [bold italics are the current authors] it is unnecessary to point out its defects. The smaller sizes are still sold extensively; and being manufactured in large quantities, they are sold very cheaply when the quality of the lenses is taken into consideration. Therefore, until some manufacturer concentrates his efforts upon production of the more convenient forms, and turns them out in very large numbers, the vertical microscope will probably maintain its place in the market, and many beginners will be led into buying an instrument which, even in its most complete and perfect form, will almost certainly be a source of dissatisfaction. Whenever a sum greater than three or four dollars is to be expended, some form other than a vertical microscope should be chosen.

Figure 10. Drum or vertical microscope

> Occasionally microscopes of this kind are furnished with achromatic objectives of pretty fair quality. In such cases the objective and eye-pieces, if they could be applied to a better stand would be worth more than the whole microscope in its original form.

Other field microscopes were also made, to much more satisfactory and professional standards, particularly those made during the "Great Age of the Taschenmikroskop", (see our four Part paper in previous issues of Micscape [xii,xiii,xiv,xv]).

However, at the beginning of the 1930s a seminal, and for field microscopes, a "sea change" event took place. Dr. John Norrie McArthur invented and produced the prototype of his first folded-optics microscopes. He had discussed this microscope before the Quekett Microscopical Club in 1933. This compact instrument was approximately 10 cm x 6.5 cm x 5.0 cm. During WW II McArthur was captured by the Japanese in Borneo, but allowed quite a bit of freedom, and thus had a chance to personally use his newly designed microscope. It was from this experience, using his own instrument that allowed McArthur at the end of the war to make some important functional changes to his folded-optics design.

McArthur microscopes were subsequently made by Hearson, Watson, C.T.S., Prior, Kirk, McArthur himself [xvi], and Vickers.

The original McArthur design, lead to a number of other folded-optics descendants. These include, to name a few, the ubiquitous plastic Open University (OU) McArthur, the Nikon H[xvii], the Swift FM-31 [xviii] and its clones, and the TWX-1 microscope discussed below.

As noted in the introduction, other folded-optics designs will be discussed by the authors in future papers.

The TWX-1

Social, Economic, and Political Background

In April 1969 the first of a string of "cultural revolutions" came to a close, with Chairman Mao established as the supreme ruler and Lin Baio, the former Minister of National Defense, and a close Mao associate appointed Vice Chairman and identified as Mao's successor. The *Quotations from Chairman* Mao became widely popular.

Figure 11. Symbol of the PLA

This was also a time of internal strife, with two main opposition forces lead on one side by Mao's fourth wife Jiang Qing and the Gang of Four, and on the opposite side Zhou Enlai, the first Premier of the People's Republic of China. (As an aside, it was the removal of the displays mourning Zhou's death in 1976 by the Gang of Four that lead directly to the Tiananmen Square uprisings.)

It was also the time when China became alarmed at the activity of the Soviet Union, as Russia built up its troops along the Soviet-Chinese border. It was against this background of a now common enemy of the Chinese people, that the Chinese army [the People's Liberation Army (PLA)][xix] (Fig. 11) became even more important to China, and its power and prestige grew even further. Before 1969 the PLA played a significant political role in promoting the Cultural Revolution, although it was not its catalyst. The PLA also took a role in political affairs. However, with the external threats facing China, the PLA was directed in mid-1970s to remove itself from politics and concentrate on improving its military strength.

By 1969, facing external threats, China realized the need for internal political and economic stability and the importance of a strong Chinese Army to defend the country. (The PLA at this time was probably the world's largest Army, although not modernized). It was also the time China became aware of its need for foreign "friends", or at least better diplomatic relationships.

In 1971 mainland China took over the China seat in the UN, displacing Taiwan. Shortly after, it began to establish diplomatic relationships with other major countries, Japan in 1972, and the exchange of ambassadors with the UK the same year. However, it was not until 1979 that diplomatic relations with the U.S. were established.

With the military threats facing China, including its military skirmishes with South Vietnam, China decided to modernize its Army. It is in this context of the changing internal political and social environment in China, and the continuing increase in importance of the PLA throughout the 1970s [xx] that the development of the TWX-1 microscope for the Chinese Army should be considered.

The Microscope

Model Designation: "TWX-1"

Manufacturer: TaiYuan Optical Instruments
Location: Taiyuan, Shanxi Province, China
Production Year: 1970s
Dimensions: Approximately 5.1" x 2.0" x 4.3". Weight about 2.5 pounds.

Figure 12. TWX-1

Description

This microscope was manufactured by the TaiYuan Optical Company of Shanxi Province, China. Taiyuan is the largest of Shanxi's cities, and is a Chinese engineering center. It is the home of Shanxi Medical University and Shanxi University. The University's Quantum Optics Laboratory is one of China's major research facilities. Today, Taiyuan continues to be the home of considerable optical research and development.

The TWX-1[xxi] (Figs. 12, 13) is solidly-built with its components mounted to a composite metal sub-structure, see below. The silver colored body plates are made of a surprising composite of metals and lightweight materials. This became evident when we examined their elemental composition with a Niton XL3t GOLDD portable X-Ray Fluorescence analyzer.[xxii] The composition, we found - in relative weights, was aluminum 16.25% ±0.25, copper, 4.26% ±0.03, sulfur% 2.75 ±0.04 and other relatively heavy trace elements, and about 76.07% ±0.38 of other lighter weight elements. Because the XRF analyzer measures only elements with atomic number 12 (magnesium) and above, it means that the composite material of the TWX-1 contains a majority of lighter weight elements.

Atomized aluminum powder was used in military high explosives, and after WW II its use widened to include the development of metallurgical products[xxiii]. Thus, the plates were possibly constructed using a powered metallurgy (P/M) process, i.e., combining powdered aluminum and copper with a binder that allows the final product to have special properties , e.g., including here, keeping its metallic appearance, staying lightweight, and having a high resistance to moisture and chemicals. However, the actual production process used awaits further study. Starting in the last century there has been significant progress in developing paints and composite materials relatively resistant to solvent damage, allowing finishes and materials other than solid metals to be used successfully in microscope construction.

This microscope, manufactured during the 1970s, was built exclusively for the Chinese army (PLA) frontline field hospital use. The Chinese army, during this and succeeding decades, up to the present, was likely the world's largest army. Although this microscope's production was limited to army field hospital use, it was probably provided to "friendly" armies of other countries. It was not sold in the open market and all copies available today, that are known to the authors, come from those "surplused" by the PLA.

This microscope is one of those uncommon Chinese products not designed for export or consumer use. Rather, it was designed for internal PLA use. During the time of its development the PLA was probably the most powerful component of Chinese society and, perhaps reflecting this, the TWX-1 was developed and built to exceptionally high standards.

Figure 13. TWX-1 from different angles

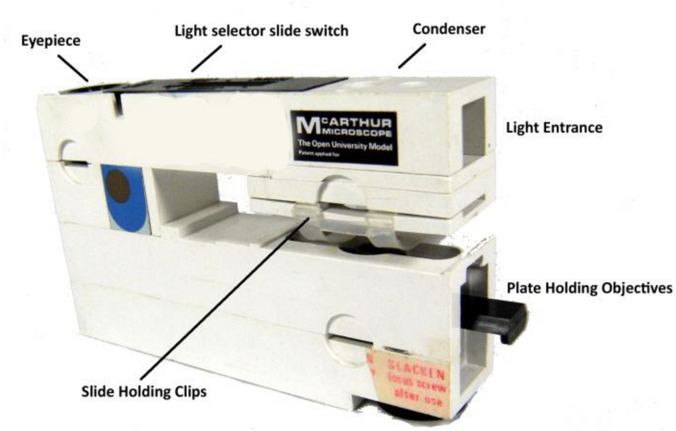

Figure 14. OU McArthur microscope components

Optical Heritage. The optical design of the TWX-1 (Fig. 16) derives from the folded-optics microscopes of John McArthur. But there are important optical differences. To compare these differences the TWX-1 is contrasted here with the ubiquitous Open University (OU) McArthur microscope. This microscope is

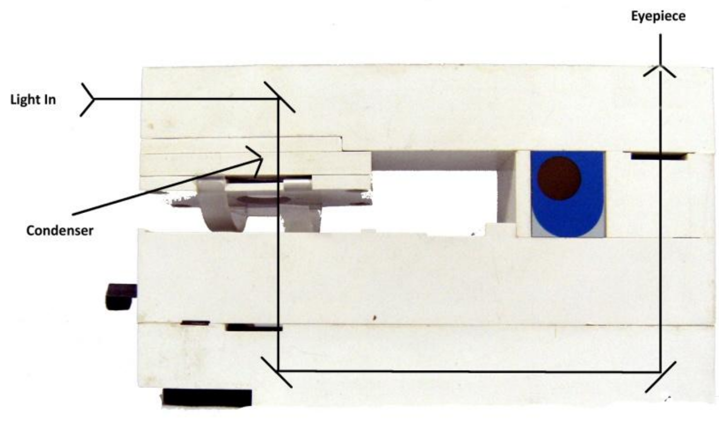

Figure 15. OU McArthur microscope optical path

unusual in its plastic construction material (the copolymer, acrylonitrile butadiene styrene). However, the comparison is perhaps unusually appropriate, as this microscope, although made by Scientific Optics Ltd., Sussex, England, was adapted by John McArthur for the OU[xxiv]. It was sent to students starting in 1971, at the same time the TWX-1 was being manufactured and distributed to Chinese army field hospitals.

In both microscopes the optical path is folded. On the McArthur, it is "folded" at three right angles. After light enters the microscope (Fig. 14, 15), it is reflected at a right angle into an objective lens. The light path then travels down through the objective where it's again reflected at a right angle and travels across the long axis of the microscope. It is reflected a third time to the viewer's eyepiece (Fig. 15). In less expensive McArthurs and folded-optics descendants, e.g., the FM-31, mirrors are used in place of prisms to reduce costs.

As can also be seen in Fig. 14, the McArthur microscope has a sliding bar/plate that holds the objectives "in line". Objectives are moved into or out of the optical path by moving the bar out from the microscope or into the microscope. The light selector slide switch identified in Fig. 14 is used to choose between external light from above the microscope, external light from the front of the microscope, or use of an internal battery, or transformer, operated light source. Notice that here the light source and condenser are above, and the objectives below, the object. However, the last light bend allows the light to be reflected upward into, the eyepiece, so the image is viewed from above.

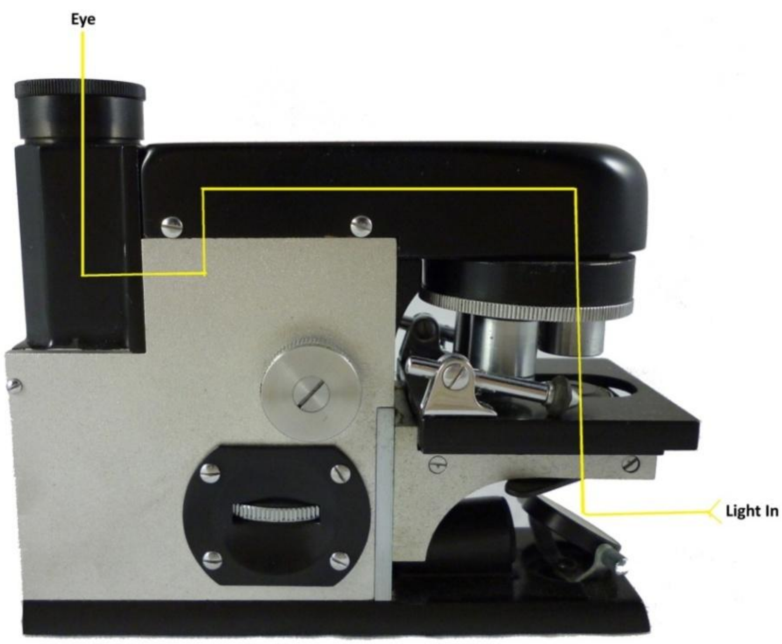

Figure 16. TWX-1 optical path

The optical path of the TWX-1 (Fig. 16) is a bit more complex, allowing slides to be viewed "right-side" up rather than upside down (inverted) as on McArthurs. There are five light bends on the TWX-1. The first is due to the mirror and its angle is variable. The other four are at right angles.

Packaging Heritage. The rounded body shape of the top portion of the TWX-1, its mirror mount (Fig. 17), the shape of its stage opening, and the essentially squared-cornered resting 'U' shape appear to have precedents in the military hospital microscopes used by the North Vietnamese, during the Vietnam War. The microscope (Fig. 18) in Billings #458 [xxv] has a similarly shaped upper body, mirror mount, stage opening, and relatively square-'ish' "U" shape. In addition, although the color of the North Vietnam hospital microscope is not visible in (Fig. 18), its black and white photo from the Billings collection catalog, the dark and aluminum toned colors of this microscope, when seen in color, and the TWX-1 are quite similar.

Figure 17. TWX-1 mirror also showing the built-in light

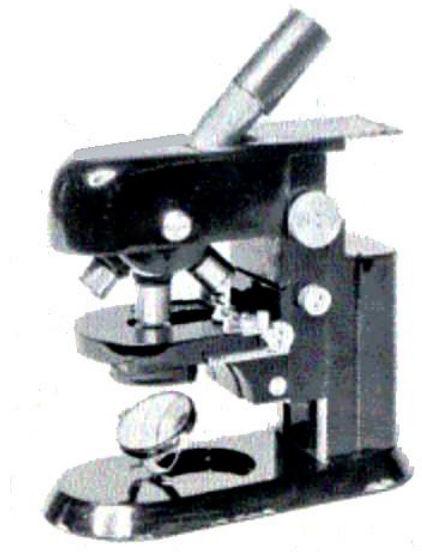

Figure 18. Billings collection, #458, North Vietnamese hospital microscope - w permission and courtesy of the NMHM

The Billings catalog notes,

> The instrument is not signed and totally devoid of markings except for the number "660271". It was used by the North Vietnamese in a large hospital complex overrun by U.S. Forces. It is unique in its compactness and is suitable for routine procedures.

The numbering scheme for the captured North Vietnamese microscope appears identical to that used on the TWX-1 (see below). That is, its six digit serial number likely begins with a two digit production year (here 66 for 1966) followed by a four digit chronological production number. If so, this microscope was manufactured in 1966, and it's quite likely, by the same Chinese company that made the TWX-1.

Although China and Vietnam had a history of border disputes, distrust, and military skirmishes, these disagreements were put on temporary hold after the U.S. entry into the War in Vietnam. During the war, China was a strong ally of North Vietnam. Thus, it's highly likely this microscope, as with much of North Vietnam's military supplies, e.g., weapons, pharmaceuticals, etc. was supplied by China.

The Vietnam conflict started in November of 1956 and lasted until April 1975 with Saigon's capture. However, significant US involvement began only after the Gulf of Tonkin resolution in 1964, authorizing then US President Lyndon Johnson to pursue "all necessary measures", which allowed for the significantly increased involvement of US forces. With the long history of US participation in this conflict, the Billings collection was contacted to see if their accession files might provide more information [xxvi] on the date this microscope was obtained in Vietnam. This could support, or disprove, the dating conjecture presented above. However, as the Billings Collection has recently moved to a new location with the National Museum of Health and Science, the accession files for this microscope are not yet available. Billings was kind enough to offer to contact the authors' should any additional material become available. If so, this paper will be updated accordingly.

The North Vietnamese hospital microscope is optically conventional, i.e., a non-folded-optics microscope, albeit of small size suitable for field use. Thus, one may reasonably conjecture that the TWX-1 was derived from the hospital microscope used by the North Vietnamese, and it's probable that both the North Vietnamese hospital microscope and the TWX-1, were developed by the same Chinese design team.

The construction materials used in producing the TWX-1 are fairly unique. The Billings collection does not yet, at its new location, have the equipment in-house to perform chemical composition testing. The authors' hope that during the spring of 2012 they will have the opportunity to compare the construction materials used in the production of the Vietnamese microscope in the Billings collection, using the Niton XL3t GOLDD portable X-Ray Fluorescence analyzer, to see if it and the TWX-1 microscope are made of similar materials, and thus the packing heritage also extends to the materials used.

Optics

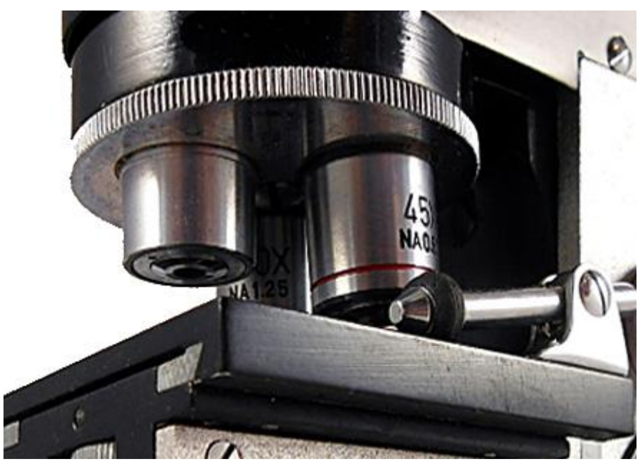

Figure 19. TWX-1 mounted objectives

Figure 20. TWX-1 unmounted 10X objective

The TWX-1 comes with three mounted objectives (Fig, 19) :

(1) 10X NA 0.25 (Fig. 20)
(2) 45X NA 0.63
(3) 90X NA 1.25

It has one mounted 10X eyepiece, and another 15X eyepiece (Figs. 21, 22) stored in a quite cleverly concealed and covered compartment on the rear of the microscope. That compartment also holds the batteries, double AA, for the internal (Fig. 17) light source. See Fig. 21 for a picture of this compartment with its storage cover opened, showing the knurled handled to move the spare eyepiece forward for removal, and the battery storage compartment with batteries removed.

Figure 21. Hidden eyepiece and battery storage compartment

Figure 22. Eyepiece removed from its holder

The optical system provides sharp images with good contrast and color at all magnifications albeit with some field curvature. The TWX-1 provided some of the best images of all field microscopes we've examined.

Mechanics

Figure 23. Knurled wheel of triple turret, stage slid inward

Objectives are changed by rotating the knurled turret wheel (Fig. 23). Objectives lock into place with a "click" and are easily changed. The advantage of a triple turret, over e.g., the standard McArthur flat bar containing the objectives, is that any non-selected objective can be selected directly, i.e., with a single turn clockwise or counter-clockwise. However, with three objectives McArthurs it is may be necessary to move past an undesired objective.

Slides are held on the stage with two spring loaded clips with rubberized bands at their ends (Fig. 24). This feature was likely adopted from the 1960s Nikon H, which uses similar clips. The slide under examination can be moved from left to right by pressure at its edges to locate the appropriate position along the X-axis, and the entire stage moves outward and inward to allow positioning the slide along the Y-axis (Figs. 23, 25).

Figure 24. Slide in place

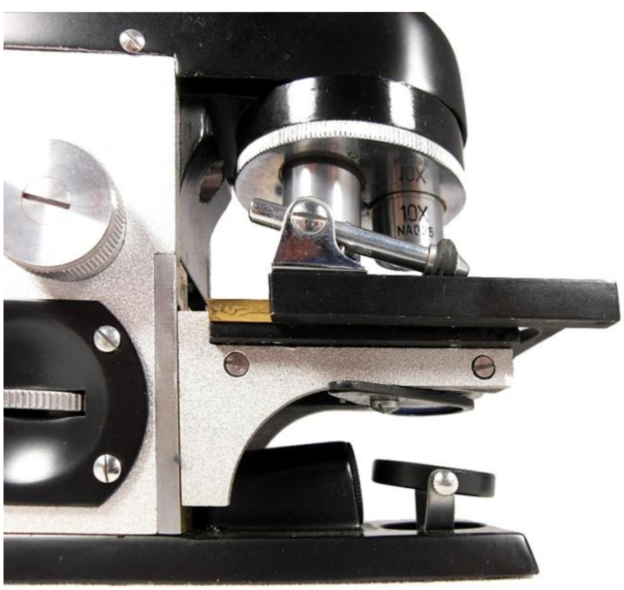

Figure 25. Stage slid outward, away from the microscope

There are both coarse and fine focusing controls available. Coarse focusing is adjusted using the lower milled wheel inside the black surround (Fig. 25), again a concept probably borrowed from the earlier Nikon H. However, the designers of the TWX-1 also included fine focusing via a knob above the course focusing control (Fig. 25). This welcome addition enables the coarse focusing to move the stage at higher range, enabling more tolerance in the use of slides of different thicknesses. This is a considerable advancement compared to other McArthur microscopes and descendants, and is a major improvement over other folded optics microscope designs.

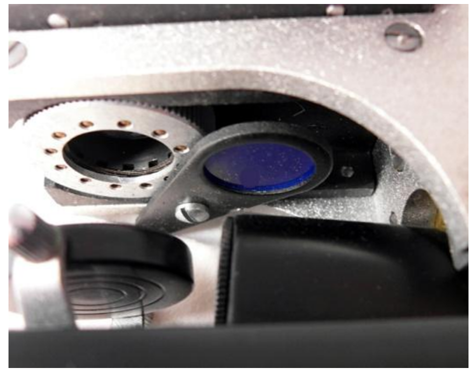

Figure 26. Substage blue filter

The substage is fairly complete, providing a swing in/swing out blue filter (Fig. 26) and a condenser with adjustable iris diaphragm, the aluminum toned bottom of which is visible in Fig. 26. The iris diaphragm is adjustable via a milled knob (Fig. 27) that is accessible just below the front of the stage. As a side note we may add, that when the blue filter is replaced by a polarizer and a companion polarizer inserted with the eyepiece, the TWX-1 can be converted into a very convenient field polarizing microscope, much superior to the very few still existing polarizing models of, e.g., the OU McArthur or the Swift FM-31.

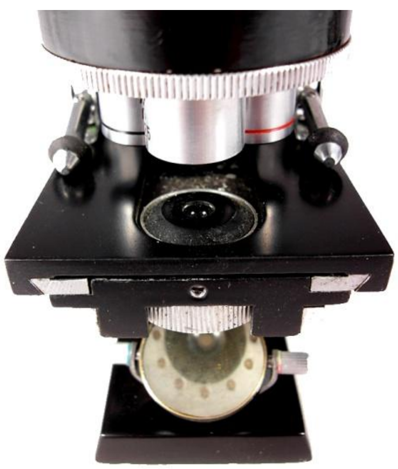

Figure 27. Iris diaphragm control knob

The TWX-1's illumination system uses two AA batteries (Fig. 21) and a small incandescent flashlight bulb (Fig. 28). Both the batteries and bulb are easily accessible. The bulb is accessed via a flat panel (Fig. 28) on the bottom of the microscope. The bulb output is via a small opening between the mirror and the microscope (Fig. 17) and can optionally be used if daylight is unavailable or inconvenient to use.

Figure 28. Bulb access

Accessories

The microscope comes with a small instruction booklet (Fig. 29), and may include a packing slip indicating date of manufacture - which is not always available, both the booklet and packing slip are written in Chinese. The tables and illustrations are easy to understand, even if you don't read Chinese. The serial numbering system seems to be easy to decipher (also see North Vietnamese microscope discussion above) as it appears to begin with a two digit representation of the production year (e.g., 74 for 1974), followed by a four digit chronological production number. If this supposition is correct, *at least* 1,500 microscopes were made, based on the serial numbers in our collections.

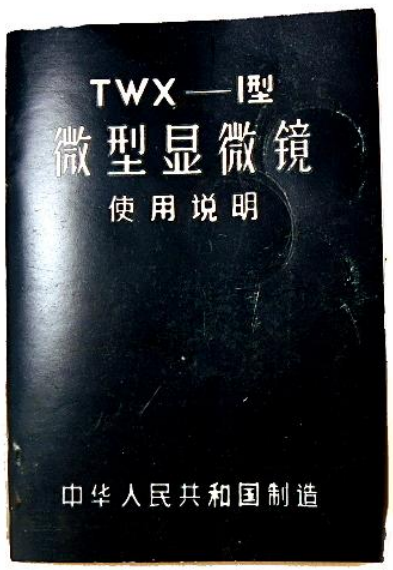

Figure 29. TWX-1 information booklet

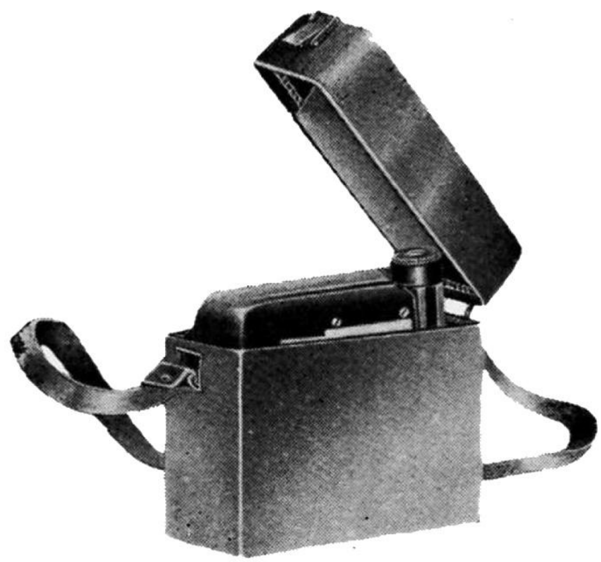

Figure 30.Microscope in hard-sided case, image from booklet

The microscope is stored in a hard-side case, colored military green, with a shoulder strap for easy and safe transportation and storage (Figs 30, 31)

Figure 31. Hard-side storage case

Conclusion

In the authors' opinions this is likely the most functional and capable folded-optics field microscope ever made and, arguably, one of the best field microscopes of all times. The Chinese maker took the concept of the McArthur microscope recognizing the improvements made in the Nikon H models, and advanced the folded-optics concept even further by designing an optical system to view slides from above.

Thus, the TWX-1 is considerably more functional and convenient to use than the Nikon H or its McArthur cohorts, offering viewing of slides right-side up, not upside down as in McArthurs and their other inverted microscope descendants. Perhaps the only drawback of this microscope, possibly as a result of its intended use for field hospital work, such as blood and urine examinations, is the presence of only three objectives, and thus the lack of a low magnification option (e.g., 4X or 5X) for wider views.

Whereas the TWX-1's cohorts were distributed relatively widely, but never in very large numbers, the TWX-1 was made only for the Chinese Army and so was manufactured for a quite restricted audience. The authors can only wonder why this model wasn't copied by others or offered for civilian use. Perhaps manufacturing costs made this impractical. Because it was made in limited quantities it is, compared to its folded-optics relatives, fairly uncommon. A few TWX-1s were placed in storage in the 1970s, for possible future military deployment, and these were "surplused" by the PLA a few years ago.

The latest folded-optics microscopes under development are the interesting Millennium Health Microscopes (MHMs). They are currently undergoing tests at the Liverpool School of Tropical Medicine (LSTM) using a large collection of Malaria slides. When these tests are completed, assuming they are successful, the MHMs should be available for public release. The authors look forward to the opportunity to test these to see how they "stack up" to the competition. We hope to present the results of these examinations in a future paper. It should be remembered that these microscopes follow the tradition of other McArthur descendants and still use an inverted design. The MHMS were apparently designed with a primary goal of detecting malaria. The results of their performance in this area awaits the completion of their evaluation at the LSTM. However, their general applicability will require additional testing.

While FM-31 clones are available (Ref 1.) and relatively inexpensive, the authors' suspect a competent microscope maker, e.g., Motic (Hq China), Nikon or Olympus (Hq Japan), Leica or Zeiss (Hq Germany), Swift (Hq US), or others would be able to revive the superior TWX-1. With today’s advanced production technology, better and less expensive materials and optical performance, such a microscope would be a very welcome addition to the extremely limited choices of professional-level field microscopes.

Bottom-line.

The optical and mechanical functionality of the TWX-1 makes it the best field microscope examined by the authors, superior even to the excellent Protami, examined in an earlier paper (Ref. xiv). The TWX-1 is, in the authors' opinions, possibly the finest field microscope ever made.

The authors would appreciate any suggestions for corrections, improvement, or expansion. They can be contacted at:

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In particular, any information on TWX-1 production numbers, and/or their manufacturing processes would be appreciated.

End notes

[i] R.J. Kreindler, Y. Goren. 2011. *Comparison of the Swift FM-31 Portable Field Microscope and an FM-31 Clone*. Micscape Magazine, March 2011.
Comparison of the Swift FM-31 Portable Field Microscope and an FM-31

[ii] Carpenter, William B. (Edited by W. H. Dallinger) *The Microscope and its Revelations. Eighth Edition*. Philadelphia: P. Blakiston's Son & Co, 1901, Figures 99 and 100, pg. 132

[iii] Dobell, Clifford (ed). *A Collection of Writings by the Father of Protozoology and Bacteriology, Antony van Leeuwenhoek and his 'Little Animals'*. London: John Bale Sons & Danielson, 1932

[iv] Ibid

[v] Ford, Brian J. *Single Lens. The Story of the Simple Microscope. New York: Harper & Row, Publishers, 1985. pp 3-4*

[vi] Ibid Ref ii,, pg 134 Figure 102

[vii] Withering, William. *A botanical arrangement of all the vegetables naturally growing in Great-Britain with Descriptions of the Genera and Species .... Volume II*. Birmingham: 1776

[viii] Brewster, D. (ed.). *Volume XIV of The Edinburgh Encyclopaedia in Eighteen Volumes*. Edinburgh: William Blackwood, 1830, p219

[ix] Kreindler, R. Jordan. *Victorian 'Live Box' Microscope Capability in 40mm* . Micscape Magazine, June 2011
Victorian 'Live Box' Microscope

[x] Kreindler, R. Jordan. *Baker's Traveller's Microscopes.* Micscape Magazine, May 2011.
Baker's Traveller's Microscopes

[xi] Phin, John. *Practical Hints on the Selection and Use of the Microscope. Intended for Beginners*. New York: The Industrial Press, 1877

[xii] Goren, Y. and R. J. Kreindler. *The Great Age of the Taschenmikroskop, Part I*. Micscape Magazine, July 2011.
The Great Age of the Taschenmikroskop Part 1

[xiii] Goren, Yuval and R. Jordan Kreindler. *The Great Age of the Taschenmikroskop, Part II. Serious Amateur and Professional Instruments*. Micscape Magazine, August 2011.
The Great Age of the Taschenmikroskop Part II

[xiv] Kreindler, R. Jordan and Yuval Goren. *The Great Age of the Taschenmikroskop, Part III. High-End Professional Instruments*. Micscape Magazine, September 2011.
The Great Age of the Taschenmikroskop Part III

[xv] Goren, Yuval and R. Jordan Kreindler. *The Great Age of the Taschenmikroskop, Part IV. Decline and lasting influence.* Micscape Magazine, October 2011.
The Great Age of the Taschenmikroskop Part IV

[xvi] Journal of Microscopy (Published on behalf of the Royal Microscopical Society). Volume 183, Issue 2, pps 181-186, *Obituary for John Norrie McArthur 1901-1996,* Willey-Blackwell, August 1996. Available on-line at
http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2818.1996.1050648.x/abstract

[xvii] http://www.microscopyu.com/museum/modelh.html

[xviii] Ibid i

[xix] PLA symbol taken from a 120 FEN, 2007 Chinese stamp

[xx] One of the authors lived in China two decades later. Even in the 1990s the deference shown the PLA was clear. While chauffeured, with a PLA General Officer in his car, they were waived through red lights by uniformed traffic police, and allowed to drive on sidewalks to bypass the traffic jams common in Beijing.

[xxi] For another review of the TWX-1 microscope, from a different viewpoint, see the articles (in German) by M. Mach in the Feb-Jul 2010 volumes of *Das Bärtierchen-Journal*,
http://www.baertierchen.de/archiv.html

[xxii] For technical data: http://www.niton.com/Niton-Analyzers-Products/xl3/xl3t.aspx?sflang=en

[xxiii] Davis, J.R. *Powder Metallurgy Processing.* in Aluminum and Aluminum Alloys, ASM Specialty Handbook. Materials Park, Ohio: ASM International, 1993, starting pg 275

[xxiv] Burall, P. *The Open University Microscope*. Design Journal, Volume 282 (June 1972), pp. 32-33, http://www.vads.ac.uk/diad/article.php?year=1972&title=282&article=d.282.30

[xxv] Purtle, Helen R. (Technical ed.) . *The Billings Microscope Collection. Second Edition*. Washington, D.C.: Armed Forces Institute of Pathology, 1987, p 228, Figure 458 (Catalog number: M- 030.00541, AFIP accession number: 518,969, MIS photograph: 73-3899)

[xxvi] The authors would like to thank Mr. Jim Curley of the National Museum of Health and Medicine, the Billings Collection, for his courteous help and support.

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